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THE FAT-SOLUBLE VITAMIN CONTENT OF THE LIVER OIL OF THE BURBOT[1]

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The burbot, *Lota maculosa*, is known by a variety of names—ling, eelpout, lawyer, freshwater cod, and freshwater cusk—to mention some of the most common. It is the only freshwater member of the cod family, all its relatives living in the sea. Many authorities consider that the American and the European species, *Lota lota*, are closely related, if not identical. If the two are to be regarded as the same species, then the geographical range of the burbot is nearly co-extensive with the fresh-waters of the northern hemisphere. Its habitat has been recorded by Small (*37*), Day (*13*), Goode (*20*), Forbes (*18*), Jordan (*26*), Jordan and Everman (*27, 28*) and Jordan, Everman and Clark (*29*). Halkett (*21*) found that the burbot was "well-nigh cosmopolitan in northern North America, recorded from Labrador, and ranging from New Brunswick westward to British Columbia; and from the Arctic regions southward to the northern States." Dymond (*17*) found burbot in Lake Nipigon, and Mackenzie (*30*) in Silver Lake, Ontario.

The burbot is a very heavy cannibal feeder, destroying large quantities of marketable fish, chiefly ciscoes and perch. Judging from the catches in a survey made at intervals from September 1928, to September 1930, its most common associates are whitefish, herring and lake trout. It is a food competitor with the last, subsisting chiefly on ciscoes and alewives, although many stomachs contain the deep-water sculpin, and at certain seasons the burbot seems to have eaten *Mysis relicta* almost entirely. As an example of their appetite, an examination of one stomach showed thirty-nine sculpins, six alewives, one herring seven inches and one herring nine inches in length. The burbot is so abundant in deep water that it is a nuisance to the fishermen who find it in great numbers in gill nets, particularly those set for whitefish. There is little or no market for burbot as food and hence the fisherman must either remove it from the nets and throw it overboard or bring the catch to shore and bury them.

If a market is created for this fish as edible food—and plans for such a market are being considered—the liver oil would be a valuable by-product.

Body Weight and Liver Weight.—Some 356 burbot, 189 males and 167 females, obtained during this survey, were measured, weighed in the round and their livers removed and weighed. Their body weights varied from 7 pounds 7 ounces to 1 pound 4 ounces, with an average weight of

[1]A contribution from the Department of Biochemistry, University of Toronto, and the Nutritional Laboratories, Department of Poultry Husbandry, Ontario Agricultural College.

This work formed part of a thesis submitted for the degree of Doctor of Philosophy in the University of Toronto.

3 pounds 3 ounces. The fish were taken in 6½-inch, 4-inch, and 3-inch mesh gill nets in depths of water ranging from 40 to 200 feet, being most common between 75 and 125 feet.

The liver weights varied from 13 ounces to 2 ounces with an average weight of 5.1 ounces. Thus the liver makes up about 10% of the body weight, being relatively much larger than the liver of the cod.

Extraction of Oil.—The method used for extraction of the liver oil was a laboratory modification of the direct steam method which is now almost universally used for the extraction of medicinal cod liver oil. The livers were removed in fresh condition from the burbot, the gall bladder removed, and the livers then washed in cold water. The livers were placed in a 3-litre beaker and steam was led in by a perforated tube extending to the bottom.

The mass of livers was subjected to steam for 45 minutes with intermittent stirring. After cooling, the mass was placed in a flannelette, canvas, or aeroplane-silk bag and allowed to drain. The oil was separated from the water by means of a separatory funnel. After draining, the "chum" remaining in the bags was pressed under increasing pressure, until no more oil could be expressed. All supplies of oil were then combined and filtered through Chardin paper to remove all liver particles.

Yield of Oil.—Twenty determinations of the percentage yield of oil were made during the survey at intervals of several months. These varied from 31.2 to 48.5% with an average of 38.4%. Similar determinations made with cod livers throughout the summer months of 1928, showed a variation from 14.0 to 37.4% with an average of 28.2%. During the course of this investigation Clow and Marlatt (*12*) using a modification of the indirect method of steam extraction reported a yield of oil varying from 36 to 56%. Apparently the livers of the burbot, as well as being relatively larger, contain more oil than those of the cod. The oil was of pale yellow colour and compared favourably in colour and taste with medicinal cod liver oil. Nelson, Tolle and Jamieson (*34*) reported that burbot liver oil has chemical and physical properties very similar to those of cod liver oil.

VITAMIN A ASSAY

1. Biological

A preliminary study by McCollum and Simmonds (*31*) indicated that 2% of cod liver oil and 3% of burbot liver oil were effective in the prompt cure of incipient xerophthalmia. In a private communication McCollum informed the writer that these statements rested upon experiments done in his laboratory about 1920, on burbot liver oil obtained from Sturgeon Bay, Wisconsin. Branion (*6*, *7*, *8*), reported that burbot liver oil was a potent source of vitamin A.

Since the conclusion of this investigation Nelson, Tolle and Jamieson (*34*) have found that burbot liver oil, prepared under commercial conditions was from 4 to 10 times as potent in vitamin A as good grades of medicinal cod liver oil.

The quantitative estimation of vitamin A, as described by Sherman and Munsell (*35*), which is essentially the method adopted by the United States Pharmacopeia, was used with the modifications suggested by the Accessory Food Factors (Vitamins) Committee ([illegible]), primarily the in-

clusion of vitamin D in the diet. Young albino rats of 40–50 g. weight, 20–30 days old are placed on a vitamin A free-diet, until growth ceases. After seven days of stationary or declining weight, the source of vitamin A under test is incorporated in graded doses, into the diet. Not only is there a cessation of growth in the young when vitamin A is deficient but both young and old show a decline in health usually terminating in death. Mellanby and Green (*33*) have indicated that these characteristic symptoms are associated with an undermining of the body resistance to infection. Experimental animals used for this type of assay must have at the time growth ceases such a disturbance in metabolism that recovery, even when vitamin A is fed, must be extremely slow. Moreover, the present trend of vitamin therapeutics, lies in the direction of prevention rather than cure. Many inherent difficulties, primarily individual variations in response, are encountered in this assay. Such difficulties have been clearly summarized by Drummond (*14*, *15*). In the author's opinion, if biological assays are to be continued in use, a "preventive" type of assay should be substituted. A modification of the assay of Sherman and Munsell, using the same diet, but including graded doses of the oil under test in the A-free ration from the beginning of the experiment, and basing the potency on the minimal daily dose which will give normal growth and prevent the onset of infection over an eight week period, has given fair satisfaction. This minimal dose is usually less than the minimum using the curative assay. A comparison of the quantities of various vitamin preparations necessary to induce the same rate of growth, rather than a growth rate of 3 grams a week, appears to be more satisfactory. In both assays irradiated ergosterol (viosterol) was used as a source of the antirachitic vitamin.

The Sherman and Munsell assay requires young rats from mothers kept on a fairly strict ration. This ration is supposedly not deficient in vitamin A but contains sufficient to meet the requirements of the nursing mother without enabling her to pass on a store to the young, which are to be used as test animals. Difficulties were encountered with this stock ration even when 1% of calcium carbonate was substituted for part of the sodium chloride, as recommended by Smith (*38*). The litters were apparently born in good condition, but in numerous cases the mother refused to nurse them. At other times the mother did nurse her young but they did not thrive and died within a week. When the breeders were continued on this ration for a period of months, the number of litters, and the size of the litters was markedly reduced. The antirachitic requirements of the stock colony were assured by irradiated ergosterol.

The addition of 10 cc. of fresh milk daily to the nursing mother during pregnancy and the first two weeks of lactation overcame these difficulties. There was no appreciable increase in the time required for cessation of growth in young rats from mothers kept on this regime. This would seem to suggest that Sherman's diet is deficient in vitamin A. The obvious conclusion was a deficiency in the powdered wholemilk. Various brands of powdered milk gave no better results. In a private communication Sherman advised the feeding of fresh lean meat to the stock colony.

Further investigation showed that the addition of 2% to 5% of dried brewer's yeast improved the growth of young rats kept on Sherman's diet. The subsequent addition of the yeast in the breeder's diet alleviated some

of the difficulties. An improvement in the general well-being of the colony was also achieved by the feeding of green stuff, lettuce or cabbage, daily.

Furthermore, when young rats, whose mothers were kept on the original diet, were placed on the A-free diet, growth ceased within a week, instead of the usual three to five weeks. Such results would indicate that Sherman's ration is deficient in fat-soluble vitamins and in some fraction or fractions of the water-soluble B complex. Sherman and Smith (*36*) point out that their diet was not recommended as an optimal food either for growth or for reproduction. During the latter experiments the stock diet of Steenbock, as modified by Bills (*4*) was used with excellent results.

Some investigators claim that the development of xerophthalmia or keratomalacia in young rats, kept on a vitamin A deficient diet, precedes the cessation of growth. In fact, Steenbock and Coward use the cure of this incipient xerophthalmia as their sole criterion for vitamin potency, paying little or no attention to growth. Our results, in general, substantiate the findings of Brocklesby (*10*) that cessation of growth precedes the onset of xerophthalmia.

After the preliminary period for the exhaustion of the vitamin store, the oil was fed in various dilutions for 35 days. The use of the 5-week test period was decided upon in view of the progressive decrease in the rate of growth encountered in rats after 3 months of age, as pointed out by Hume and Smith (*25*) and Drummond and Morton (*14*). Even using this shorter test, in some instances the rate of growth of the rats under test was much less during the last weeks. This failure of growth could not be made good by increasing the amount of the vitamin supplement.

In the earlier experiments paraffin oil was used for the dilution of the burbot oil. In later experiments sesame or corn oil was used. Several investigators have questioned the ability of the test animals to absorb mineral oils, and any vitamin preparation dissolved in them might be only partially absorbed, the remainder being swept out of the intestinal tract. The sesame or corn oil was always assayed to ascertain the absence of vitamin potency in these oils. Our results showed that .002 g. of the liver oil using paraffin oil for dilution was the minimum daily amount necessary to promote the required growth, whereas diluted with a vegetable oil, .0016 g. was the minimum dosage; being a difference in potency between 500 and 625 units. The use of the word "units," however, suggests a degree of accuracy which is not justified. Biological assays should be considered as approximations only as Ahmad and Drummond (*2*) pointed out.

Some thirty biological assays for vitamin A potency were carried out. Oils extracted from livers obtained from burbot caught at different months of the year were assayed to show any seasonal variations in potency. These assays indicated some variations, the potency increasing from the time of spawning to the late winter or early spring, and reaching a maximum in August or September. The results must be considered, however, in view of the inaccuracy of biological assays, as merely indicating a general trend. Future investigations may permit more definite conclusions. All assays showed a vitamin potency of 500 units or better.

The results are summarized in Table 1 and are the averages of all experiments.

TABLE 1.—VITAMIN A POTENCY OF BURBOT LIVER OIL

Source of vitamin (daily)	Increase in weight (35 day test period)	Incipient xerophthalmia
.020 g. oil	42 g.	Cured
.010 g. oil	40 g.	Cured
007 g. oil	43 g.	Cured
004 g. oil	25 g.	Cured
.003 g. oil	24 g.	Cured
.002 g. oil	19 g.	Cured in 90% of cases, improved in all cases

Not less than three animals were used in each assay for each dose of oil, the oil being administered orally to individuals. Negative controls, fed the deficient ration, were maintained with each experiment. In all assays these controls lost weight and died during the test period. Litter mates and males and females were divided among the groups as far as possible.

Typical growth curves are given in Figures 1, 2, and 3.

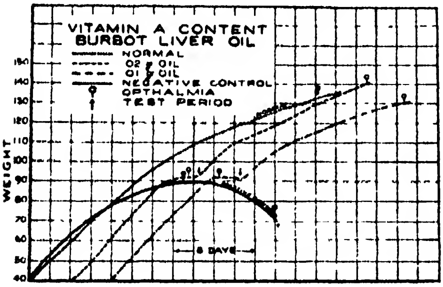

FIGURE 1. Growth curves of rats, showing the growth promoting properties of a daily dosage of 02 g. and 01 g. of burbot liver oil, added to a vitamin A deficient diet, after cessation of growth. For comparison, the growth curve of a rat on a normal diet and one on the vitamin deficient diet with no supplement, are included.

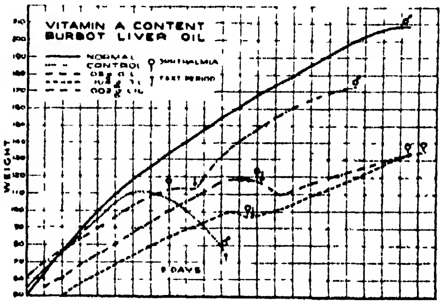

FIGURE 2. Growth curves of rats showing the growth-promoting properties of a daily supplement of 02 g., 004 g. and 002 g. of burbot liver oil to a vitamin A deficient diet.

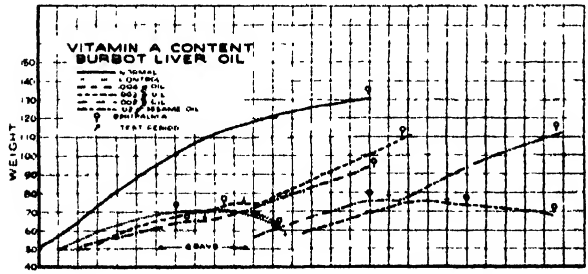

FIGURE 3. Showing the growth-promoting properties of a daily supplement of 004 g., 003 g. and .002 g. of burbot liver oil to a vitamin A deficient diet. The failure of a daily dose of .02 g. of sesame oil to promote growth is also shown.

The results of the biological assays show that burbot liver oil is a potent source of vitamin A. Based on this assay, its potency would be 500 units per gram. The U.S.P. requirement for medicinal cod liver oil is 50 units per gram, although most medicinal oils contain from 250 to 500 units.

The daily administration of .002 g. of the oil in every case gave at

least the weekly growth of 3 grams as required by the method. The incipient ophthalmia was not completely cured in all cases with this minimum dosage, but there was a marked improvement. Since, as had been pointed out, this type of biological assay does not seem to give the accuracy necessary for a minute determination of unit potency, without the use of a prohibitive number of animals, it was felt that further assaying of greater dilutions was not warranted. The oil is at least as potent in vitamin A as most, if not all, medicinal cod liver oils.

It was observed in the course of these assays and of other assays carried out with various samples of cod liver oil during the period, that increasing dilution of the oils sometimes leads to a level of dosage which will promote growth of 10 to 20 grams, or even better, in 35 days, but which seems to exert little or no curative effect on the induced ophthalmia. A possible explanation of these observations would be a dual nature of vitamin A. Such a suggestion has been advanced by other workers in this field. These results indicate a line of attack which might prove fruitful in the establishment of this duality—A_1 being a growth factor and A_2 the anti-infective factor.

It is of practical importance that the vitamin A content of burbot liver oil, kept at room temperature in a bottle which was opened for a few minutes three times a day, dropped from a potency of 500 units per gram to less than 50 units in six months.

2. Colorimetric

For the colorimetric assay of vitamin A the antimony trichloride method was used, as adopted by the Accessory Food Factors (Vitamins) Committee (*1*). This is comparable to Drummond's (*15*) technique B. Burbot liver oil, in 10% solution, gave blue colours ranging from 12.6 to 13.6 Lovibond units, with an average of 13 units, measured on a Rosenheim-Schuster tintometer. A medicinal cod liver oil measured at the same time gave a blue colour of 8.6 units. Various cod liver oils assayed by the same methods have varied from 6 to 12 blue units. Drummond suggested that cod liver oil for human consumption should show greater than 7 blue units measured by Technique B.

The colorimetric assay would rank burbot liver oil as an excellent source of vitamin A.

VITAMIN D ASSAY

The preliminary study of McCollum and Simmonds (*31*) showed that burbot liver oil contained the antirachitic vitamin. Clow and Marlatt (*12*), also using the liver oil of burbot caught in Sturgeon Bay, reported that burbot liver oil could be classed with cod liver oil as an excellent source of the antirachitic vitamin. As a matter of fact it was about eight times as potent as the particular medicinal oil against which it was tested. Branion (*7*, *8*) reported that burbot liver oil was a potent source of vitamin D. Since these assays were finished Steenbock, Kletzien and Halpin (*40*) and Halvarson (*22*) have demonstrated that burbot liver oil will serve as an antirachitic agent for young chicks. Nelson, Tolle and Jamieson (*34*) found this oil to be 3 to 4 times as potent in vitamin D as medicinal cod liver oil.

EXPERIMENTAL

Young albino rats, 30 days old, from a stock colony kept on Bills' diet, were placed on McCollum's (*31*) rachitogenic diet No. 3143 or on Steenbock's (*39*) rickets-producing diet No. 2965. Preventive rather than curative assays were carried out since it was felt that the present therapeutic use of antirachitic preparations was in the direction of the prevention rather than in the cure of rickets. The burbot liver oil was fed daily by mouth in varying dilutions with sesame oil, and its vitamin potency was judged by Roëntgen-ray examination of the knee-joint, made at the end of a 30 day test period. Negative controls were maintained on the diet without oil. Inorganic blood phosphate determinations were carried out by Brigg's (*9*) modification of the method of Bell and Doisy, on the pooled blood from each group of animals.

Some difficulties have arisen in the production of rickets by the use of either rachitogenic diet. Mild anorexia and cessation of growth, followed by the "spontaneous cure" of the induced rickets has not been uncommon. The addition of a small amount of green feed daily (lettuce or spinach) has usually improved the rats' appetite.

Harris and Bunker (*23*) reported on the irregularity of the development of rickets which they believed to be due to antirachitic properties of the corn. Goldblatt (*19*) claimed that this irregularity on the rachitogenic diets either 2965 or 3143 was due either to the settling out of the calcium carbonate or to inanition. In this laboratory the addition of 5% dried brewer's yeast to diet 2965 has entirely alleviated the difficulties. This indicates that inanition and poor growth are the cause of the irregularity.

Some typical results of the inorganic blood phosphorus determinations are given in Table 2.

TABLE 2.—INORGANIC BLOOD PHOSPHATE

Diet	P in mg per 100 c.c. plasma		
	I	II	III
Normal	9.0	6 5	6 3
Rachitogenic No. 3143	1 9	—	—
Rachitogenic No. 2965	—	1.8	2.8
Rachitogenic + .020 g. burbot liver oil	5 9	6 6	—
Rachitogenic + .010 g. burbot liver oil	4 0	3.4	—
Rachitogenic + .004 g. burbot liver oil	2 6	4 3	3.1
Rachitogenic + .003 g. burbot liver oil		4.1	3 5
Rachitogenic + .002 g. burbot liver oil		3 2	3.2
Rachitogenic + .0016 g. burbot liver oil		4.4	4.3
Rachitogenic + .0013 g. burbot liver oil		2.7	
Rachitogenic + .020 g. 1X Viosterol*		4.0	
Rachitogenic + .020 g. Sesame Oil		1.1	

*250 D or 100 X viosterol was diluted to 100 volumes, *i.e.* to the vitamin D potency of a good cod liver oil.

According to Cavins (*11*) the normal inorganic phosphorus level of rat blood serum is 7 to 8 mg. per 100 cc. and in rachitic animals on a low phosphorus diet (McCollum 3143) as 2 to 3 mg. Dutcher, Creighton and Rothrock (*16*) found the concentrations to be 8 mg. and 1.6 mg. per 100

cc. respectively. In the course of these experiments the normal inorganic plasma levels varied from 5.5 to 9.0 with an average of 6.9 mg. per 100 cc. and the rachitic levels from 1.3 to 4.4 with an average of 2.7 mg. per 100 cc. However, as Hess, Weinstock, Rivkin and Gross (*24*) have reported a lack of relationship between the development and cure of rickets and the inorganic phosphorus concentration of the blood, it is probable that blood phosphorus levels give little more than a qualitative indication of the course of rickets.

Figure 4 shows some Roëntgen-ray photographs of the knee-joint of typical individuals, together with the inorganic blood phosphorus levels of the pooled group which they represent, obtained during the course of experimental work on rickets in rats.

It is seen that there is no direct relationship between rickets and the inorganic phosphorus, other than a general indication of the condition. The Roëntgen-ray photograph of Rat 52 reveals very severe rickets and the plasma inorganic phosphorus was 3.8 mg. per 100 cc., whereas the Roëntgen-ray examination of Rat E1 shows no sign of rickets and the plasma inorganic phosphorus was 2.6 mg. per 100 cc. The photograph of Rat 12 shows little, if any, sign of rickets with a plasma inorganic phosphorus of 1.5 mg. per 100 cc. These results confirm the findings of previous investigators. The values given in Table 2 also show no uniformity of blood phosphorus levels with the vitamin intake.

Roëntgen-ray examination of the knee-joint definitely establishes the presence or absence of rickets and further will, in most cases, show the deposition of any new-formed bone. It is not suggested that this examination should take the place of the various modifications of the original line test of McCollum, Simmonds, Shipley and Park (*32*), but if suitable X-ray facilities are available it seems to be as satisfactory, especially in a preventive type of assay.

Four series of such photographs with burbot liver oil in graded doses are shown in Figures 5, 6, 7 and 8. The fifth series shows results obtained with two medicinal cod liver oils.

Series 1, using a liver oil obtained from burbot caught early in June, shows that the lowest dosage of oil, .004 g. daily, gave much better bone formation than the control, although it did not completely protect from rickets.

In series 2, using a July oil, similar results are shown, .004 g. daily being the lowest level which gave complete protection. However, still lower doses down to a .0016 g. daily intake gave improved bone formation over the control, and all show evidence of bone deposition. The lowest level .0013 g. daily shows little if any improvement over the rachitic animals. The levels of oil from .003 g. to .0016 g. daily seem to have afforded protection equal to that given by .02 g. of a 1 × preparation of viosterol.

An August oil, used in series 3, gives evidence of protection at a daily intake of .004 g. and shows bone deposition at an intake of .002 g. but a daily dose of .0016 g. shows no evidence of therapeutic value.

As will be seen in series 4, the use of .0016 g. of September burbot liver oil has afforded complete protection against rickets. These results

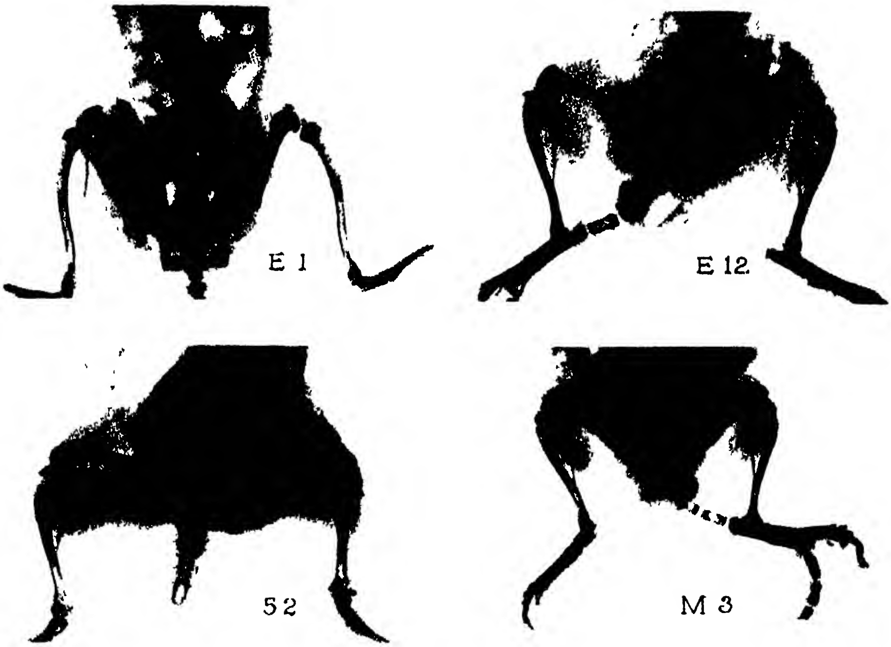

FIGURE 4 Roentgen-ray photographs of knee-joint of rats fed rachitogenic diet 2965. E 1—Plasma inorganic phosphorus 2.6 mg. per 100 cc (No rickets) E 12—Plasma inorganic phosphorus 1.5 mg. per 100 cc (Very slight rickets) 52 Plasma inorganic phosphorus 3.8 mg per 100 cc (Severe rickets). M 3—Plasma inorganic phosphorus 2.8 mg per 100 cc (Fairly severe rickets).

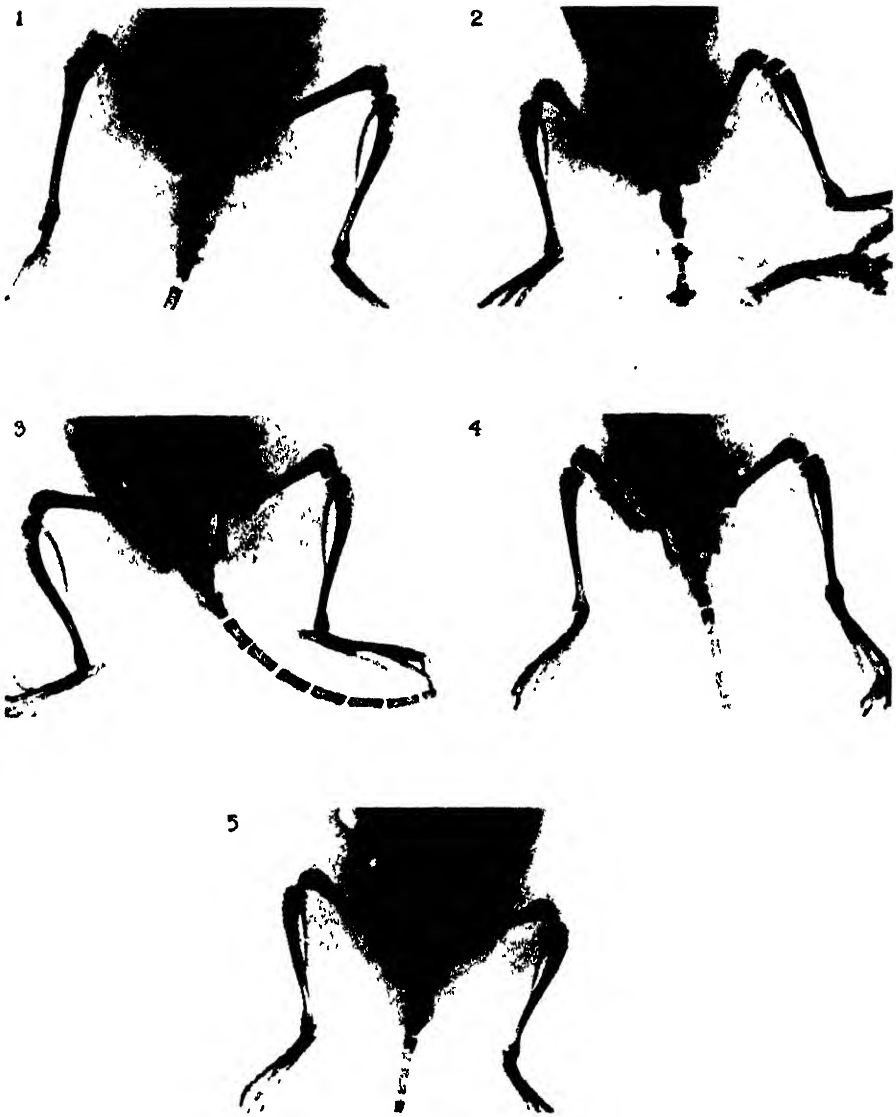

FIGURE 5. Antirachitic potency of June burbot liver oil. Series 1. Roentgen-ray photographs of knee joints. 1. Normal. 2. Rachitic. 3. Rachitic plus .02 g. of oil. 4. Rachitic plus .01 g. of oil. 5. Rachitic plus .004 g. of oil daily.

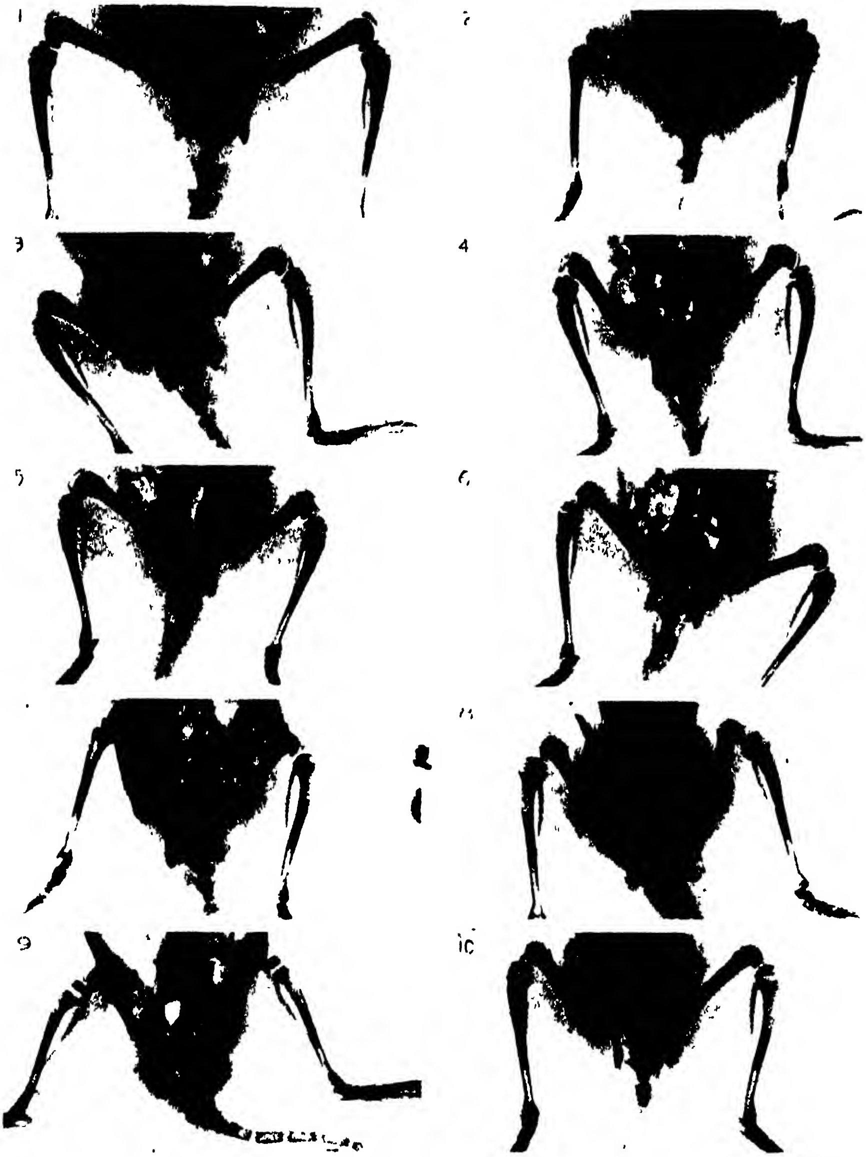

FIGURE 6. Antirachitic potency of July burbot liver oil. Series 2.—Roentgen-ray photograph of knee joints. 1. Normal. 2. Rachitic. 3. Rachitic plus 02 g. of oil. 4. Rachitic plus 01 g. of oil. 5. Rachitic plus 004 g. of oil. 6. Rachitic plus 003 g. of oil. 7. Rachitic plus 002 g. of oil. 8. Rachitic plus 0016 g. of oil. 9. Rachitic plus 0013 g. of burbot liver oil, daily. 10. Rachitic plus 02 g. of 1 X viosterol daily.

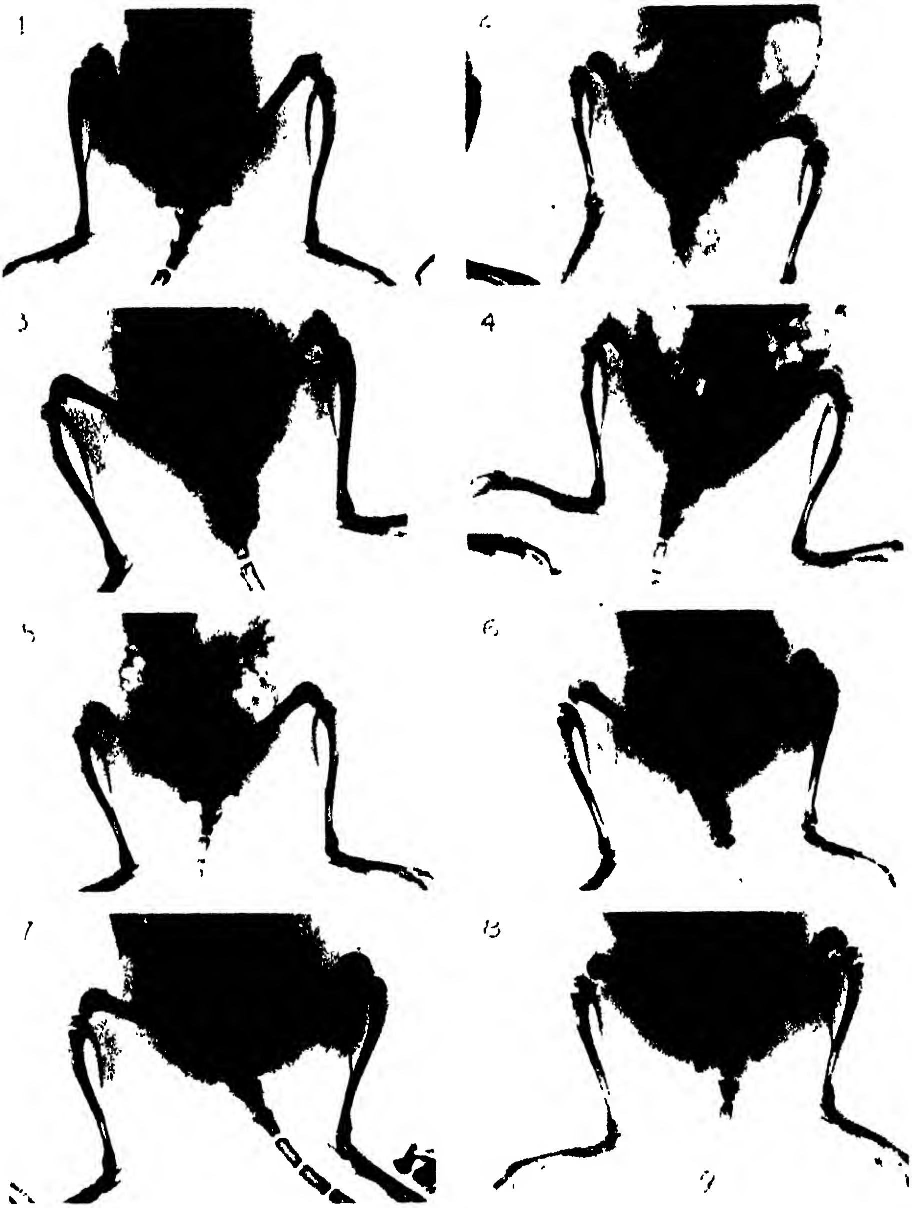

FIGURE 7 Antirachitic potency of August burbot liver oil. Series 3 Roentgen-ray photographs of knee joints 1 Normal. 2. Rachitic. 3. Rachitic plus .02 g. of oil 4 Rachitic plus .01 g of oil 5. Rachitic plus .004 g of oil. 6 Rachitic plus .003 g. of oil 7 Rachitic plus .002 g. of oil. 8. Rachitic plus .0016 g. of burbot liver oil daily.

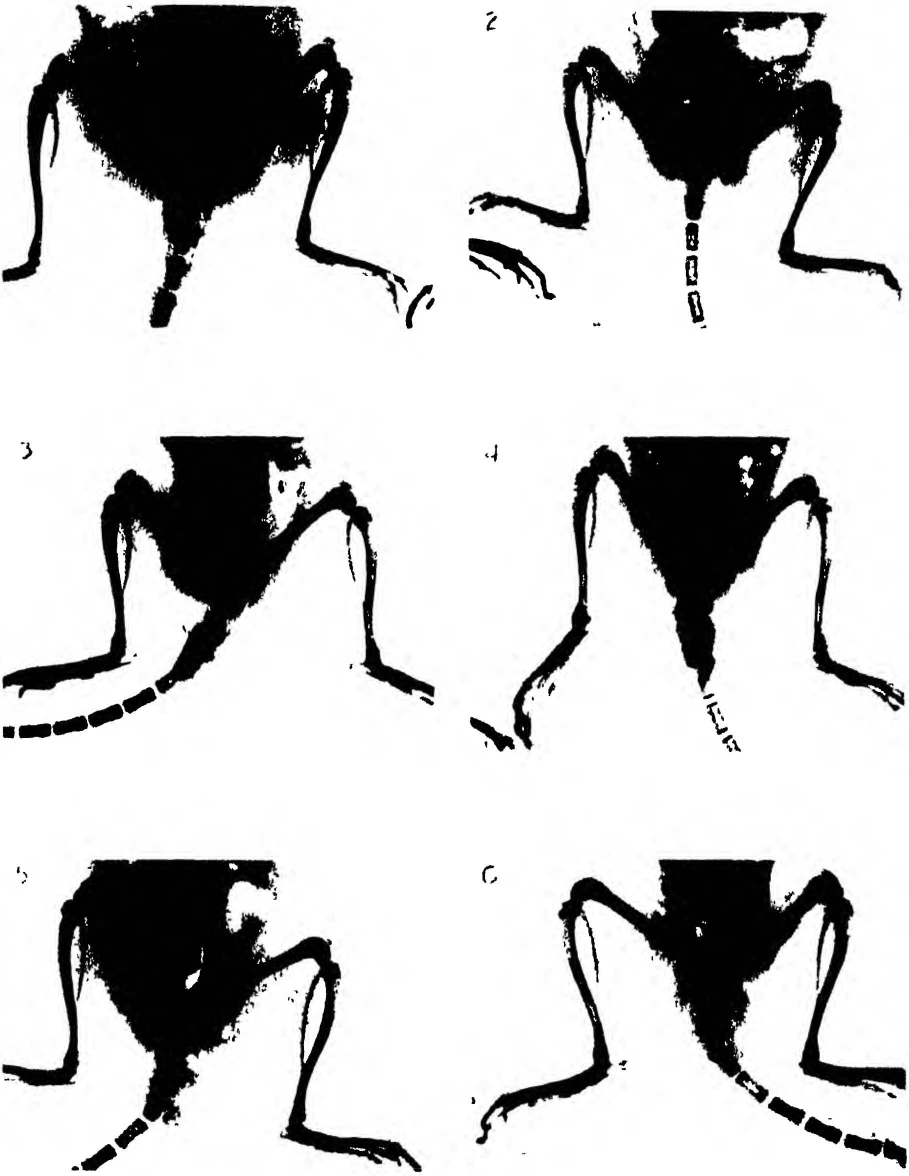

FIGURE 8. Antirachitic potency of September burbot liver oil. Series 4.—Roentgen-ray photographs of the knee joints. 1. Normal. 2. Rachitic. 3. Rachitic plus .004 g. of oil. 4. Rachitic plus .003 g. of oil. 5. Rachitic plus .002 g. of oil. 6. Rachitic plus .0016 g. of Burbot liver oil daily.

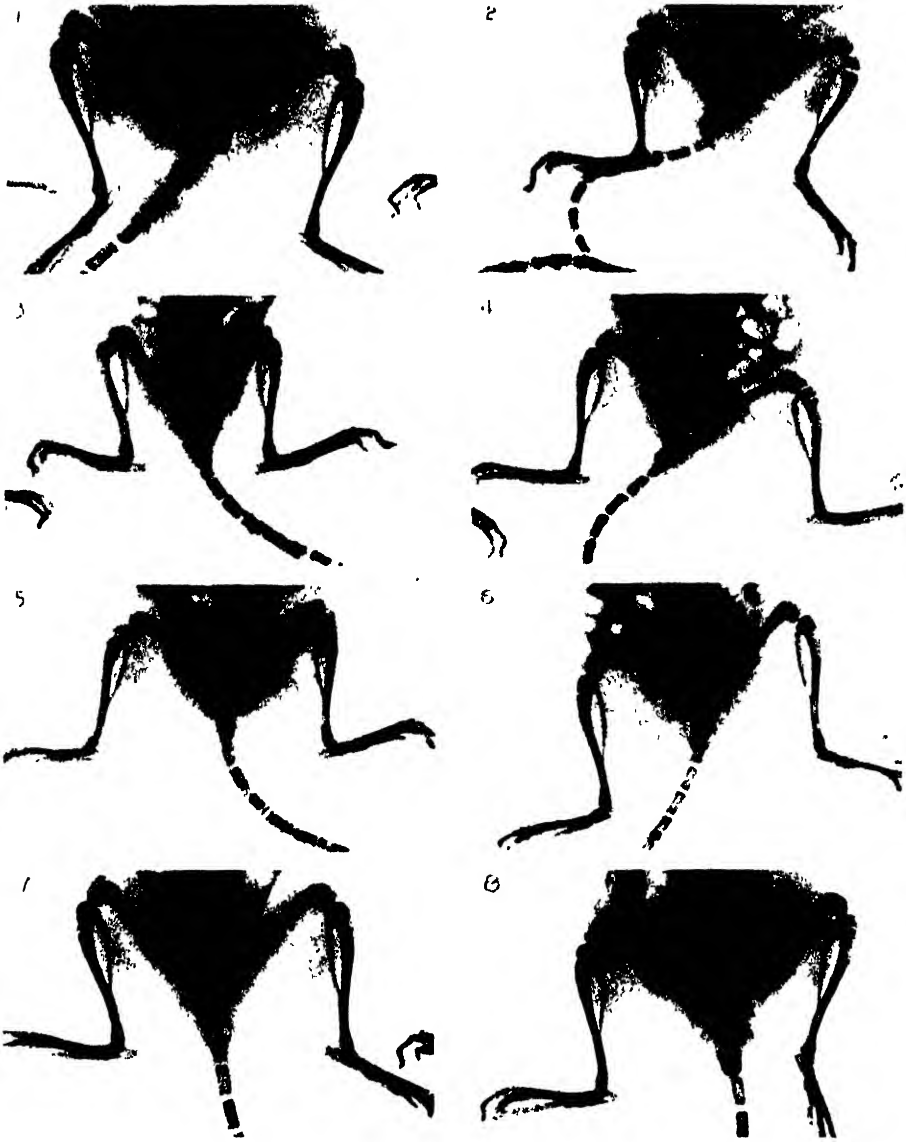

FIGURE 9 Antirachitic potency of medicinal cod liver oils. Series 5 Roentgen-ray photographs of the knee joints. 1 Normal 2 Rachitic. 3 Rachitic plus 02 g of oil. 4 Rachitic plus 004 g of oil. 5 Rachitic plus 002 g of Medicinal Cod Liver Oil No 1 daily 6 Rachitic plus 02 g of oil. 7. Rachitic plus 004 g of oil. 8. Rachitic plus 002 g. of Medicinal Cod Liver Oil No. 2 daily

suggest that the vitamin D potency of burbot liver oil, like its vitamin A content increases to a maximum in the late summer. The old theory that the ultra-violet light in summer sunshine enabled the minute plankton to synthesize vitamin D, which was passed on from smaller to larger organisms until it reached its final resting place in the liver of the fish, would explain this phenomenon. Tisdall and Brown (*41*) showed that there was a marked increase in the antirachitic effect of sunlight in the spring and summer, that received from April to August in Toronto being eight times as potent as that in the winter. However, Bills (*3*) has advanced strong evidence that fish synthesize the vitamin, even when kept in the dark.

An examination of the photographs in series 5 indicates that .004 g. of these medicinal cod liver oils gave fairly complete protection but that .002 g. of the first oil gave no protection, and of the second oil gave very little protection.

These results show that burbot liver oil has a high content of the antirachitic vitamin, being at least as potent as medicinal cod liver oil, and being more potent than the two medicinal oils against which it was tested.

These assays of the fat-soluble vitamin content of burbot liver oil show that it could be substituted for cod liver oil. With the increasing need for a good source of liver oil for incorporation into rations for domestic animals, in particular poultry, this oil should meet a popular demand. Medicinal cod liver oil is sold at an almost prohibitive price to ordinary stockmen. Cheaper grades of "cod liver oil" have appeared on the markets, but, with a few exceptions, no vitamin assay is assured.

Some of these cheaper oils, apparently obtained by the sun-rendered process, are definitely deficient at least in vitamin A. Apart from the possibility of marketing burbot liver oil for human consumption, the use of the oil in stock rations would prove a source of profit to Ontario fishermen, and would also rid the lakes of a fish which is, up to the present time, of no value and whose predatory tendencies have cost the industry many thousands of dollars.

SUMMARY

1. Burbot livers are of relatively large size and give a high yield of an oil which compared favourably in colour and taste with cod liver oil.

2. The vitamin A content of the oil is 500 units per gram or better, judged by biological assay. Antimony trichloride colorimetric assay gives a blue colour of 13 units as compared with 8.6 blue units developed by a medicinal cod liver oil.

3. The liver oil of the burbot is a potent source of vitamin D. It has a higher antirachitic potency than two medicinal cod liver oils against which it was assayed.

4. Evidence is presented to show a deficiency in the Sherman stock diet for rat colonies used in vitamin assays.

5. Inorganic blood phosphorus determinations are of little value, if used alone, in the assaying of vitamin D.

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REFERENCES

1. Accessory Food Factors (Vitamins) Committee. Estimation of vitamin A in cod liver oil. Report on a comparison between the colorimetric (Rosenheim, Drummond) and the biological method of determining vitamin A in cod liver oil. Lancet, 5447 : 148. 1928.
2. Ahmad, B., and Drummond, J. C. The relative vitamin A value of the body and liver oils of certain fish. Biochem. Jour. *24* : 27. 1930.
3. Bills, C. E. Antiricketic substances. 6. The distribution of vitamin D, with some notes on its possible origin. Jour. Biol. Chem. *72* : 751. 1927.
4. ———, Honeywell, E. M., and MacNair, W. A. Antiricketic substances. 7. Biochemical and spectroscopic studies on purified cholesterol. Jour. Biol. Chem. *76* : 252. 1928.
5. ———, ———————, Wirick, A. M. and Nussmeier, M. A critique of the line test for vitamin D. Jour. Biol. Chem. *90* : 619. 1931.
6. Branion, H. D. Some observations on the manufacture and vitamin content of cod liver oil and allied oils. Biological Board, Canada, Rept. 25. 1928.
7. ————. The marketing of ling (burbot). Trans. Amer. Fish. Soc. *60* : 199. 1930.
8. ————. The vitamin content of burbot liver oil. Can. Chem. Metall. *15* : 214. 1931.
9. Briggs, A. P. A modification of the Bell-Doisy phosphate method. Jour. Biol. Chem. *53* : 12. 1922 : and *59* : 255. 1924.
10. Brocklesby, H. N. The determination of the vitamin A content of the liver oil of the Dogfish, *Squalus sucklii*. Biological Board, Canada, Rept. 14. 1927.
11. Cavins, A. W. The effect of fasting and refeeding on the calcium and inorganic phosphorus in the blood serums of normal and rachitic rats. Jour. Biol. Chem. *59* : 237. 1924.
12. Clow, B., and Marlatt, A. L. The antirachitic factor in burbot liver oil. Ind. Eng. Chem. *21* : 281. 1929.
13. Day, F. British Fishes. (Williams and Norgate, Edinburgh), Vol. 1, 308, 1880.
14. Drummond, J. C., and Morton, R. A. Observations on the assay of vitamin A. Biochem. Jour. *23* : 785. 1929.
15. ————, and Hilditch, T. P. The relative values of cod liver oil from various sources. (H. M. Stationery Office, London). 1930.
16. Dutcher, R. A., Creighton, M. and Rothrock, H. A. Vitamin studies. 11. Inorganic blood phosphorus and bone ash in rats fed on normal, rachitic and irradiated rachitic diets. Jour. Biol. Chem. *66* : 401. 1925.
17. Dymond, J. R. The fishes of Lake Nipigon. University of Toronto Studies. Public. Ont. Fish. Res. Lab. 27. 1926.
18. Forbes, S. A. Studies of the food of fresh water fishes. Bull. Illinois State Lab. Nat. Hist. *2* : 433. 1888.
19. Goldblatt, H. Vitamin D in whole corn. Science *73* : 494. 1931.
20. Goode, G. B. The Fish and Fisheries of United States. (United States Commission of Fish and Fisheries, Washington) Sect. 1, 235. 1884.
21. Halkett, A. Check List of the Fishes of the Dominion of Canada and Newfoundland (Dept. of Marine and Fisheries, Ottawa) 79. 1913.
22. Halvarson, H. A. Annual Feed Bulletin (State of Minnesota, Dept. of Agriculture, Dairy and Food, Division of Feed and Fertilizer Control). 4. 1932.
23. Harris, R. S., and Bunker, J. W. M. Note on the corn component of a rachitogenic diet. Science *73* : 95. 1931.

24. Hess, A. F., Weinstock, M., Rivkin, H., and Gross, J. The lack of relationship between the development and cure of rickets and the inorganic phosphorus content of the blood. Jour. Biol. Chem. *87* : 37. 1930.

25. Hume, E. M., and Smith, H. H. A critical examination of methods of evaluating vitamin A by means of the growth of rats. Biochem. Jour. *22* : 504. 1928.

26. Jordan, D. S. Fishes (Appleton, New York) 743. 1924.

27. ——————, and Evermann, B. W. The fishes of North America. U.S. National Museum, Bull. 27 : 2922. 1898.

28. ——————, ——————. American Food and Game Fishes. (Doubleday, Page, and Co., New York). 1902.

29. ——————, ——————, and Clark, H. W. Check list of fishes and fish like invertebrates of North and Middle America, north of the northern boundary of Venezuela. Part II. Rept. U.S. Commissioner of Fisheries for 1928. 1930.

30. Mackenzie, A. Ann. Rept. Dept. Game and Fisheries, Ontario. 1930.

31. McCollum, E. V., Simmonds, N., Becker, J. E., and Shipley, P. G. Studies on experimental rickets. 21. An experimental demonstration of the existence of a vitamin which promotes calcium deposition. Bull. Johns Hopkins Hospital *33* : 229; and Jour. Biol. Chem. *53* : 293. 1922.

32. ——————, ——————, Shipley, P. G., and Park, E. A. Studies on experimental rickets. 66. A delicate biological test for calcium-depositing substances. Jour. Biol. Chem. *51* : 41. 1922.

33. Mellanby, E., and Green, H. N. Vitamin A as an anti-infective agent. Brit. Med. Jour. 3569 : 984. 1929.

34. Nelson, E. M., Tolle, C. D., and Jamieson, G. S. Chemical and physical properties of burbot liver oil and its vitamin content. Investigational Rept. 12. U.S. Dept. of Commerce, Bureau of Fisheries. 1932.

35. Sherman, H. C., and Munsell, H. E. The quantitative determination of vitamin A. Jour. Amer. Chem. Soc. *47* : 1639. 1925.

36. ——————, and Smith, S. L. The vitamins (Chemical Catalog Company, New York). 259. 1931.

37. Small, H. B. Animals of North America (Lovell, Montreal). Series II, 1865.

38. Smith, A. H., and Anderson, W. E. Lactation versus improved growth in stock albino rats. Science *70* : 98. 1929.

39. Steenbock, H., and Black, A. Fat-soluble vitamins. 23. The induction of growth-promoting and calcifying properties in fats and their unsaponifiable constituents by exposure to light. Jour. Biol. Chem. *64* : 263. 1925.

40. ——————, Kletzien, S. W. F., and Halpin, J. G. The reaction of the chicken to irradiated ergosterol and irradiated yeast as contrasted with the natural vitamin D in fish liver oils. Jour. Biol. Chem. *97* : 249. 1932.

41. Tisdall, F. F., and Brown, A. Seasonal variation of the antirachitic effect of sunshine. Amer. Jour. Diseases Children. *34* : 721. 1927.

Résumé

La proportion de vitamine soluble dans la graisse dans l'huile du foie de la lotte. H. D. Branion, Université de Toronto, Toronto, Ont.

Les foies de lotte (ou loche) sont relativement gros et rendent beaucoup d'huile qui soutient avantageusement la comparaison avec l'huile de foie de morue au point de vue de la couleur et du goût. La proportion de vitamine A trouvée dans cette huile est de 500 unités ou plus par gramme, jugée par l'essai biologique. L'essai colorimétrique au trichlorure d'antimoine donne une couleur bleue de 13 unités tandis qu'une huile de foie de morue médicinale développe 8.6 unités bleues. L'huile de foie de la lotte est très riche en vitamine D. Elle a un pouvoir anti-rachitique plus élevé que les deux huiles de foie de morue médicinales, contre lesquelles elle a été essayée. L'auteur présente des preuves établissant l'insuffisance du régime alimentaire Sherman employé pour les colonies de rats, utilisées dans les essais de vitamine. Les déterminations du phosphore inorganique du sang, employées seules, n'ont que peu de valeur dans la détermination de la vitamine D.

AN ACCOUNT OF THE WESTERN HEMLOCK LOOPER, *ELLOPIA SOMNIARIA* HULST, ON CONIFERS IN BRITISH COLUMBIA

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INTRODUCTION

The purpose of this paper is to present a biological study of the western hemlock looper and to point out some of the ecological factors, such as parasites, predators, and weather conditions which influence the progress of outbreaks in British Columbia. An account of three airplane dusting projects is also given, with intent to point out the difficulties which may be encountered in undertaking such control operations.

RECENT OUTBREAKS IN BRITISH COLUMBIA

Heavy defoliation by the western hemlock looper occurred on two areas in British Columbia in 1928, one at Indian River, North Arm of Burrard Inlet, and the other on Gold Creek, west shore of Alouette Lake; several minor outbreaks were also examined.

Indian River Area.—On this area, the peak year of the infestation wa in 1928. The area extended from the mouth of the river up the canyon for a distance of six miles, varying in width from one-fourth to one-half mile. There was considerable spread of the infestation in 1929.

Seymour and Capilano Areas.—Areas of severe defoliation developed in the Seymour and Capilano Valleys in 1929. The Seymour Creek infestation reached the largest proportions of any that year. It extended along Seymour Creek from a point one-fourth mile below the storage reservoir, up the canyon for a distance of twelve miles. It had an average width of one-fourth mile. The adults were extremely abundant in the fall of 1929 for several miles down the canyon below the severe infestation, and eggs were deposited there in tremendous numbers.

Mill Creek Area.—This infestation, discovered in 1929, extended from the mouth of Mill Creek, northwest shore of Howe Sound, up the canyon for at least two miles. The width did not average more than one-fourth of a mile. The area has been logged and the remaining timber is of poor quality.

Coquitlam Lake Area.—In 1929 this area had reached 640 acres in extent, situated on the west side of Coquitlam Lake, near the southern end. In 1930 this infestation gave decided evidence of rapid decline.

Alouette Lake Area.—Two areas of looper defoliation were discovered near Alouette Lake in 1928. The one on the west side, near the lower end, comprised 320 acres, and the other, three miles up Gold Creek, was 800 acres in extent. These infestations appeared to have subsided in 1930.

Chehalis River Area.—Two reported areas were examined on the Chehalis River in 1929. One of these, approximately 400 acres, was at the mouth of the river where considerable defoliation occurred. The other area was situated five miles up the river. There was noticeable defoliation there in 1929, and great numbers of adults were noted that fall. The feeding was not heavy in 1930, possibly indicating a subsidence.

Popkum Area.—A small infestation was located at Popkum in November, 1929. This is near the Fraser River, about ten miles east of Chilliwack. It comprised twenty-five acres, but an inspection in September, 1930, indicated a definite subsidence.

Stanley Park.—Although there was no complete defoliation in Stanley Park in 1929, some of the trees lost from 30 to 40% of their needles and the moths were numerous in spots, indicating a rising infestation. Control measures on this area are dealt with later.

BIONOMICS

After considering all of the infested areas, it was decided to carry on an intensive study of the Indian River infestation.

The coniferous stand of this area consists of hemlock, *Tsuga heterophylla* Sarg., 60%; cedar, *Thuja plicata* Don., 20%; Douglas fir, *Pseudotsuga taxifolia* Britt., 12%; sitka spruce, *Picea sitchensis* Traut. and Mayer, 5%; and balsam, *Abies grandis* Lind., 3%. In some of the canyons there were a few scattered white pines, *Pinus monticola* Dougl., particularly on the northern portion of the area. The deciduous trees occurring on the area are alder, *Alnus sitchensis* Sarg.; willow, several species; maple, *Acer macrophyllum* Pursh.; vine maple, *Acer circinnatum* Pursh.; red elderberry, *Sambucus racemosa* L.; and wild crab-apple, *Pyrus rivularis* Dougl. The shrubbery consists of salal, *Gaultheria shallon* Pursh.; blueberry, *Vaccinium* sp.; huckleberry, *Vaccinium ovatum* Pursh.; salmonberry, *Rubus spectabilis* Pursh.; spirea, species undetermined, and thimbleberry, *Rubacer parviflorum* Rydb.

Oviposition

The egg of the western hemlock looper is .75 mm. long by .50 mm. in diameter, ovoid in shape, minutely, hexagonally reticulate, slightly compressed and with a saucer shaped depression at one end. In the centre of this depression there is a small tubercle. The eggs are bluish green when first deposited but under natural conditions soon turn to a pale yellow-white colour and remain thus throughout the winter. In the spring, just prior to hatching, they become dark gray with a graphite sheen. After emergence of the larvae the egg cases are semi-transparent with pale iridescent colours.

Six attempts to induce females to oviposit in confinement ended in failure.

Place of Oviposition.—Eggs were found on the undersides of hemlock needles, and on stems of branchlets, both on reproduction and on mature trees, from the lowest branches to the tops, generally placed near the base of the needle or at the middle, rarely near the tip. They were generally deposited in groups of from two to ten, rarely singly In only one case were eggs found on the upper needle surface but here the situation was protected by the eaves of a house. In one or two instances eggs were found on the under surface of maple leaves *(Acer macrophyllum)*. These were the dried leaves of the previous season which were on the ground and probably had fallen subsequent to oviposition.

Eggs were found in the greatest numbers in moss, on limbs and trunks of practically all trees on the area. In this case the eggs were nearly always

deposited singly, glued to a single moss strand. Egg counts were made as follows:—

In one linear foot of moss from a hemlock limb three-fourths inches in diameter—78 eggs.

In one linear foot of moss from a hemlock limb one-fourth inch in diameter—120 eggs.

In one linear foot of moss from a vine maple trunk one and one-eighth inches in diameter—175 eggs.

Eggs were also found on the forest floor. Eighty-five eggs were found in one square foot of moss. These were attached singly to the moss strands. However, there were many places on the forest floor where no eggs could be found. Oviposition in such situations probably occurs only when the moths appear in extremely large numbers at the very peak of an infestation. A few eggs were found deposited in lint beneath the eaves of a house.

Hatching of eggs had already commenced when the area was first examined, on May 22nd, and many young larvae could be seen clinging to the hemlock needles and leaves of deciduous trees and shrubs. As many as twenty-four were counted on the under surface of one elderberry leaf. Hatching extended over a considerable period, commencing before May 22nd and extending to June 11th. A good opportunity for studying the winter mortality was not afforded at that time, but in the spring of 1930, 705 eggs were collected from the Seymour Canyon infestation. These were placed in the laboratory at a temperature of approximately 28° C. Hatching took place as shown in Table 1.

TABLE 1.—HATCHING AND PARASITISM OF EGGS. NUMBER OF EGGS USED 705

Date	Larvae emerged	Egg parasites*
May 5	72	
May 6	108	
May 7	114	1
May 8	38	5
May 9	12	16
May 10	4	20
May 12	1	22
May 15	0	22
May 16	0	2
May 19	0	1
May 21	0	3
May 22	0	7
May 23		1
May 26		9
May 27		2
May 28		4
May 30		1
Totals	349	116

*_Telenomus_ sp. near _dalmani_ Ratz.

After sufficient time had elapsed subsequent to the last parasite emergence, the remaining eggs were opened and examined. Sixty-five more parasites were found dead which, for some reason, had failed to emerge, although apparently fully developed. The totals then became:—

Larvae hatched—349	49.5%
Egg Parasites—181	25.7%
Unaccounted for—175	24.8%

The 24.8% probably represents the winter mortality of this particular area for this particular year.

Larvae

A hemlock looper larva just hatched, is 3 mm. long and .5 mm. in diameter, annulated with alternate dark brown and light gray bands.

The larvae are remarkably uniform in colour, but after the first moult commence to vary considerably. In later stages the larvae are pale green, yellow, brown, or dark gray with irregular, narrow and wavy black lines extending longitudinally. The full grown larva is 25 mm. to 27 mm. long with a head capsule 2.5 mm. in breadth. The body diameter varies from 2 mm. to 3 mm.

The head capsule measurements fall naturally into five classes corresponding to the respective instars. The average for each of these classes is as follows:—

First instar	.42 mm.
Second instar	.68 mm.
Third instar	1.06 mm.
Fourth instar	1.55 mm.
Fifth instar	2.21 mm.

According to Dyar's rule the above figures should follow approximately a regular geometrical progression. The ratio of increase is found to be .70; then by calculation:—

Breadth in fifth instar	2.21 mm.
Calculated breadth in fourth instar (.70 × 2.21)	1.547 mm.
Calculated breadth in third instar (.70 × 1.547)	1.083 mm.
Calculated breadth in second instar (.70 × 1.083)	.758 mm.
Calculated breadth in first instar (.70 × .758)	.530 mm.

Breadths found— .42; .68; 1.06; 1.55; 2.21
Breadths calculated—.53; .758; 1.083; 1.547.

These two series correspond closely enough to indicate clearly that all of the instars are represented and none have been missed. These measurements show that for the majority of larvae moulting occurred as follows:—

First moult between June 12th and June 30th (majority)
Second moult between June 24th and July 10th (majority).
Third moult between July 7th and July 24 (majority).
Fourth moult between July 19th and July 31st (majority).

The ability to ascertain which instar the majority of larvae represents at a given time is important in fixing the amount of dust to use per acre in airplane dusting.

Longevity without Food.—On June 5th, twelve newly hatched larvae were placed in a glass container with a closely woven cloth bound over the top. No food was provided. The vial was placed outside as near as possible to the place where the eggs were deposited. The first death occurred on June 12th. By June 13th, three larvae were dead and four more by June 14th. All larvae were dead by June 18th. From this it is apparent that newly hatched larvae can live from seven to fourteen days without food. This indicates that it is possible for them to move some distance to reach suitable food when the eggs are deposited in unfavourable situations.

Larval Habits.—Observations on the severity of feeding both in 1928 and 1929 indicated the following preference of food plants in descending degree:—

Conifers: hemlock, balsam, Douglas fir, spruce, cedar, white pine. (No evidence of feeding was found on yew.)

Deciduous trees: willow, crab-apple, vine maple, large leaf maple, alder, red elderberry.

Shrubs: huckleberry, salmon-berry, salal, spirea, thimbleberry.

On the most severe portion of the infestation, practically all plants were stripped of foliage. Even devil's club (*Echinopanax horridum* Dec. and Planch) was fed upon to a small extent.

Experiments were carried out to determine whether larvae could be reared entirely on other foliage than hemlock. From ten to twenty young larvae were caged with each of the following plants:—vine maple, huckleberry, willow, crab-apple, spirea, cedar, and spruce. Larvae were successfully reared through to adults on spruce alone, on huckleberry alone, and on combinations of huckleberry and crab-apple, and huckleberry and willow.

The larvae in the cage containing cedar fed comparatively little and failed to develop. Larvae apparently would not eat spirea. The attempt at rearing on vine maple alone was unsuccessful, although vine maples are often stripped clean during the course of infestations.

The larvae feed very little during rainy weather but either cling by the claspers and project at an angle from the under surfaces of the leaves or suspend themselves on very short threads. During favourable weather the larvae apparently feed night and day, since the volume of sound produced by the droppings can be heard undiminished all through the night. Of course, this may be due to the larvae getting rid of the food consumed during the day. When the larvae are in the later stages of development, the sound of the droppings resembles a steady, light rain.

During fair weather the larvae often let themselves down on long silken threads, specially when disturbed. In ascending the thread two methods were noted. In one, the larva bends its head back and, reaching up with the back pair of legs, catches the thread higher up. The larva then pulls itself up by straightening out, catching the thread still higher up with the front legs. This process is repeated until the branch is regained, the thread being accumulated in a little ball between the legs and later discarded. In the later stage of an infestation, the woods are festooned with this webbing.

In the other method, which apparently can only be used in travelling along threads already established between two points, the larva loops along the thread in the same characteristic manner that it does along a twig.

The habit of dropping on threads undoubtedly serves as a means of escape from predators and as a means of rapid transference to new feeding locations by dropping from higher to lower foliage, or by dropping to the ground to crawl up some other tree or plant. It may be the means of moving horizontally when the larvae are small. The wind often carries the threads out almost horizontally and could very easily carry young larvae from tree to tree in this manner.

On June 19th, after forty-eight hours of almost continuous rainfall, examination was made to see what effect it had upon the larvae. Instances were noted where maple leaves had been stuck together by the water, drowning larvae between them. Quite a number of larvae were knocked into puddles and drowned and indications were that, over the entire area, the mortality due to the rainfall was considerable.

Pupation

Pupation occurred between August 10th and September 10th. Pupae were not noted in the field in appreciable numbers until August 13th, although a pupa appeared in one of the larval cages on August 2nd. On September 10th there were still a few larvae in the pre-pupal stage and when pupation was at its height there were still some larvae only half grown and a few even smaller. These undoubtedly were overtaken by the winter season or destroyed by some other agency before they became full grown.

The pupa is naked, 7.5 mm. to 11 mm. long and 3 mm. to 3.5 mm. in diameter. The colour of normal pupae varies considerably from light yellowish brown with dark brown pepper spots less distinct. On the wing pads the spots are merged with narrow, brown, interrupted stripes and the spots are more or less in two rows dorsally. The appearance of parasitized pupae will be referred to in the section on parasites.

Pupae were found in moss and crevices, on trunks and limbs of nearly all trees, both conifers and broad leaves. Pupation was also common on the ground beneath the trees and beneath stones, chips, or other protective objects. In severe infestations the ground is covered with them and when so located they are not generally attached to anything. Those on trunks and limbs are held in place by the moss and in addition are attached at the anal extremity.

Adult Emergence

For the study of emergence, 14,500 pupae were used. Of these 7,500 were collected from the southern end of the area which was apparently a year behind the remainder in the development of the outbreak. An additional 7,000 pupae were collected from various parts of the area farther up the river. These two lots were placed in separate cages located in the open forest as nearly as possible under natural conditions.

Moths and parasites were collected each morning and late in the afternoon. Practically all of the moths emerged in the evening and during the night so that most of them were taken in the morning collection. Table 2 indicates the days on which the pupae were collected, the number in each collection, and the emergence of moths and parasites each day.

It will be noted that the males emerged before the females, and that the former outnumbered the latter in both cages. On the southern portion of the area there were 1.8 males to one female, and on the remainder of the area, 2.3 males to one female (Table 2).

The combined emergence of the moths for the two cages has been correlated with weather conditions. It was noted that the peak of the emergence was in the midst of a period of fair weather, with low relative humidity and high temperature.

There was indicated a decided influence of weather conditions on the larval emergence of the parasite, *Winthemia cilitibia* Rand. The only apparent cause for a sudden increase in emergence on September 20th was a definite rise in humidity accompanied by rain. Weather conditions favourable to the emergence of this parasite seem to be the opposite of those favouring moth emergence. The previous high points of emergence were caused by the disturbing of the pupae when collected. Any such disturbance often causes immediate emergence. Note the difference in the figures for parasites and moths in the two cages.

The moths are very quiet during the day, resting on foliage, trunks, limbs, and on the ground, but they rise in clouds when disturbed. In the evening and during the night they fly about actively and gather about lights in great numbers. Copulation apparently takes place soon after emergence, since a number of pairs taken from the cages were *in coitu.* The moths were noticed feeding upon pear cores. In this connection it might be profitable to experiment with traps and baits.

TABLE 2.—CAGE 1—PUPAE FROM STUDY PLOT

Date	Pupal collections	Emergence of males	Emergence of females	Dipterous maggots	Dipterous adults	Hymenopterous adults
Aug. 16	238			3		
Aug. 17						
Aug. 18						
Aug. 19				7		
Aug. 20						
Aug. 21	857			3		
Aug. 22				3		
Aug. 23	1100			12		
Aug. 24	400			10		
Aug. 25				10		
Aug. 26	625			18		
Aug. 27				18		
Aug. 28	800			40		
Aug. 29		1		33		
Aug. 30	500	4		24		
Aug. 31	500	14	1	23		
Sept. 1	2000	16	1	47		
Sept. 2		33	2	16		
Sept. 3		31	1	9		6
Sept. 4		68	7	8		2
Sept. 5		104	16	6		1
Sept. 6	480	139	20	21		3
Sept. 7		182	18	17		4
Sept. 8		237	29	20		4
Sept. 9		291	73	25		2
Sept. 10		332	110	22		3
Sept. 11		391	129	27		4
Sept. 12		304	116	7	1	7
Sept. 13		230	115	8	0	8
Sept. 14		217	122	4	0	6
Sept. 15		127	104	3	0	8
Sept. 16		79	111	3	0	9
Sept. 17		74	167	0	2	6
Sept. 18		50	174	0	1	1
Sept. 19		39	112	0	0	4
Sept. 20		29	79	209	3	2
Sept. 21		8	24	6	0	1
Sept. 22		10	32	0	2	0
Sept. 23		5	14	0	2	0
Sept. 24		12	34	3	3	0
Sept. 25		3	19	3	0	0
Sept. 26		3	6	0	1	0
Sept. 27		3	6	0	1	1
Sept. 28		3	3	0	1	1
Sept. 29		0	4	0	0	3
Sept. 30		1	5	0	1	0
Oct. 1		0	4	0	0	0
Oct. 2		0	0	0	1	1
Oct. 3		0	0	0	0	0
Oct. 4		0	0	0	0	0
Totals	7500	3040	1658	668	19	87

Pupal parasitism—10%
Emergence moths—62 6%
Destroyed by fungus or other cause—27.4%

TABLE 2 (*Concluded*).—CAGE 2—PUPAE FROM THE MAIN AREA

Date	Pupae collections	Emergence of males	Emergence of females	Dipterous maggots	Dipterous adults	Hymenopterous adults
Aug. 16						
Aug. 17						
Aug. 18						
Aug. 19						
Aug. 20						
Aug. 21						
Aug. 22						
Aug. 23						
Aug. 24	225			11		
Aug. 25				0		
Aug. 26	800			12		
Aug. 27				3		
Aug. 28				2		
Aug. 29	700			35		
Aug. 30	1600			130		
Aug. 31				48		
Sept. 1		2		39		
Sept. 2		5		50		1
Sept. 3	1400	3	1	113		1
Sept. 4	1200	11	0	194		0
Sept. 5	800	23	3	238		1
Sept. 6	275	38	2	85		3
Sept. 7		47	2	65		1
Sept. 8		89	7	44		1
Sept. 9		132	14	48		0
Sept. 10		178	19	116		3
Sept. 11		194	36	39		3
Sept. 12		193	34	32		2
Sept. 13		173	38	10		3
Sept. 14		179	52	17		0
Sept. 15		166	65	4		0
Sept. 16		127	56	3		2
Sept. 17		115	63	0		2
Sept. 18		80	59	0		1
Sept. 19		46	51	2		0
Sept. 20		22	30	145		0
Sept. 21		9	9	0		0
Sept. 22		6	13	4		0
Sept. 23		13	25	0		1
Sept. 24		10	49	2		1
Sept. 25		5	48	0		0
Sept. 26		2	23	0		0
Sept. 27		7	25	0		0
Sept. 28		6	18	0		1
Sept. 29		5	21	0		1
Sept. 30		3	24	0		0
Oct. 1		4	6	0		0
Oct. 2		2	8	0	1	0
Oct. 3		0	0	0	0	0
Oct. 4		0	0	0	0	0
Totals	7000	1895	801	1491	1	28

Pupal parasitism—21.7%
Emergence of moths—38 5%
Destroyed by fungus or other causes—39 8%

In 1929 moths continued to fly from August 29th to November 17th. Only a very few moths were found active on the latter date. Shortly after the peak of the moth flight, about September 25th, the waters of the

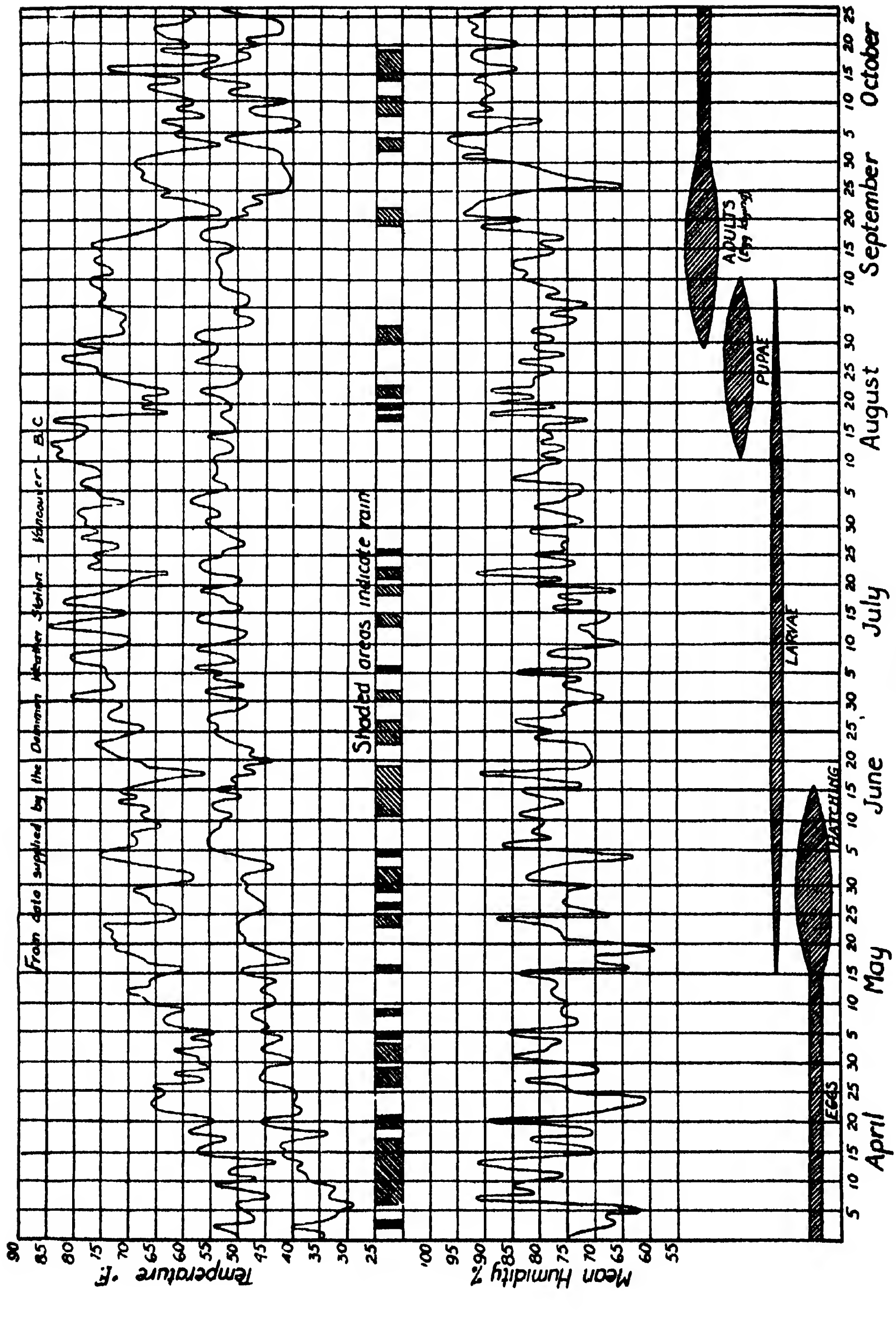

PLATE III

Progress of hemlock looper infestations in the vicinity of Vancouver, British Columbia, 1929.

inlet were covered with moths for a distance of three miles. Plate III indicates weather conditions from the time of hatching up to the time the moths had practically disappeared.

CONTROL

Parasites

The following parasites have been bred from some stage of the western hemlock looper in British Columbia:—

Diptera: *Winthemina cilitibia* Rand.
Zenillia blanda O.S.
Agria affinis Fallen.

Hymenoptera: *Amblyteles cestus* Cres.
Amblyteles sp., near *velox* Cress.
Apechthis ontario Cress.
Ephialtes (Itoplectis) obesus Cush.
Ephialtes sp.
Hemiteles sp. (hyper-parasite?)
Hyposoter sp., near geometrae Ashm.
Gelis ferruginosus Cush. (hyper-parasite).
Ichneumon sp., probably *puerilis*.
Telenomus sp., near *dalmani* Ratz.
Mastrus neodiprioni Vier. (hyper-parasite?).

Fungi: *Empusa rhizospora*.
Sporotrichum globuliferum Sperg.

The most effective parasite of the hemlock looper larvae in British Columbia is the Tachynid fly, *Winthemia cilitibia*. Under field conditions, emergence took place in 1930 as indicated in Table 3. Five hundred pupae were used.

TABLE 3.—EMERGENCE OF ADULTS OF *Winthemia cilitibia* RAND

June 23	24
June 28	32
June 30	60
July 7	81
July 11	96
July 18	26
July 26	2
Total	321 adults

The egg is deposited on the dorsum of the looper larva just behind the head or a short distance from it. Cases have been noted where eggs were deposited on the venter and behind the middle of the body. The young larvae penetrate the body of the host, gradually moving posteriorly as the host develops. It is therefore not difficult to distinguish parasitized larvae in the later stages by the noticeable posterior swelling. The larvae of the parasite emerge from the pupal cases of the host and enter the soil or forest duff where they remain all winter, pupating the following spring.

From 7,000 looper pupae, 1,491 *Winthemia cilitibia* larvae emerged between August 24th and September 24th. In another lot of 7,500 pupae, 668 larvae emerged during the same period. The influence of weather conditions on the emergence of the parasite larvae has been noted. In one instance, three fly larvae were found in one pupal case and in several instances two were found in one pupal case. Cases of double and triple occupancy did not appear numerous enough, however, seriously to affect the figure for the percentage of parasitism.

Another parasite of considerable importance is a species of *Hyposoter* which destroys the looper larvae before the latter pupate. When full grown the parasite larvae pupate and drop to the ground, where they may be found in considerable numbers beneath the trees. They often flip and roll about in the manner of Mexican jumping beans. The pupal cases are very tough, light gray when first formed, turning almost black later. They are ovoid, 4.5–6 mm. long, and 2.5–3 mm. in diameter. Adults emerged under laboratory conditions in November. One thousand of these pupae were collected and sent to Ottawa for study.

Seventy-one specimens of *Amblyteles cestus* Cress. emerged from looper pupal cases between September 3rd and September 29th under field conditions. This parasite was also bred from the oak looper of Vancouver Island by Dr. James Fletcher (*2*).

Eight specimens of *Amblyteles* sp. near *velox* Cress. emerged under field conditions from hemlock looper pupal cases between September 9th and September 30th. The place of oviposition was not determined.

Thirty-two specimens of *Apechthis ontario* Cress. emerged from hemlock looper pupal cases between August 31st and October 2nd under field conditions.

One looper larva was found parasitized by a species of *Braconid.* There were thirteen parasite larvae attached to one host which was much swollen and pale yellowish green in colour. An attempt to rear these parasites was unsuccessful.

Four specimens of *Telonomus* sp., near *dalmani* Ratz., emerged from hemlock looper eggs on June 7th, 1929, and six more on February 17th, 1930. In the spring of 1930, 705 looper eggs were collected and 181 specimens of the same parasite were recovered from this lot. This indicated an egg parasitism of 25% on the Seymour area and indicates that this parasite is sometimes an important factor in the control of outbreaks.

In addition to the above parasites, a few specimens were taken of *Mastrus neodiprioni* Vier., three of *Gelis ferruginosus,* (wingless), four of *Ephialtes* (*Itoplectis*) *obesus* Cush., one of *Ephialtes* sp., and three *Ichneumon* sp., probably *puerilis* Cress., *Hemiteles* and *Gelis* are probably secondary parasites on *Hyposoter.*

The pupae containing the larvae of *Winthemia cilitibia* Rand. are easily recognized by the dark brown colour in which the pepper spots are barely visible or have been submerged. They are also soft to the touch and easily ruptured, releasing a foul smelling fluid. When disturbed the maggot often emerges shortly afterwards. This accounts for the large emergence which took place with each collection of pupae. At the end of half a day's work the collecting can was often squirming with maggots.

The looper pupal cases containing the Hymenopterous parasites look much like normal pupae except that some of them are longer and larger and have a less solid appearance. The case is often rigid.

Two species of fungi were found to destroy the hemlock looper. The most common one was a white mould which sometimes occurred where the pupae were thickly placed in moss on the shady side of trunks. The species has not been identified.

PLATE IV

FIGURE 1—Indian River Valley, location of a severe hemlock looper outbreak.
FIGURE 2—Group of hemlocks killed by the western hemlock looper.
FIGURE 3—Stand of timber killed by the western hemlock looper.

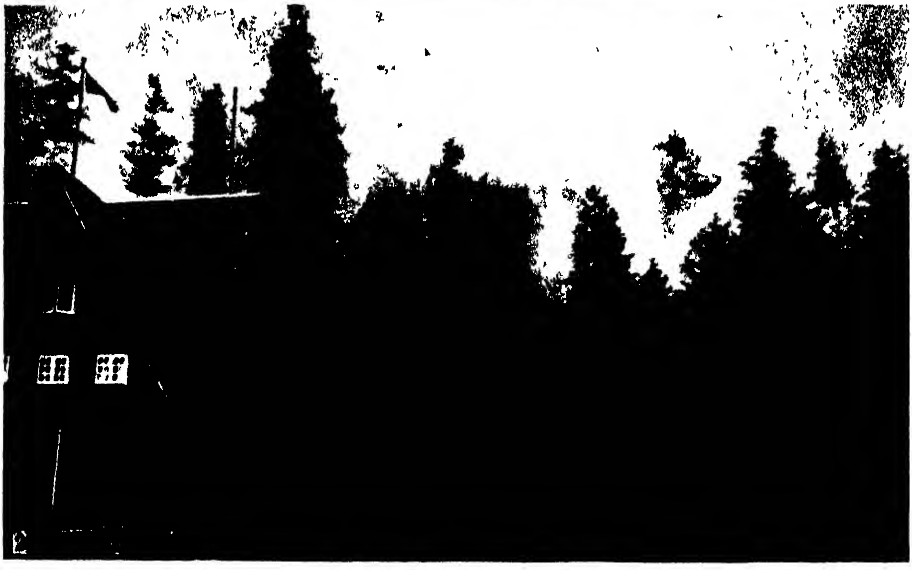

PLATE V

FIGURE 1 Airplane dusting, Seymour Canyon.

FIGURE 2--Experimental airplane dusting Wigwam Inn, showing dust settling over foliage after passing of the airplane.

Of the other fungus, only one specimen was secured. This was a dead larva with finger-like pseudo-conidia projecting from it. Judging from this single example, Dr. H. T. Gussow believed it to be *Empusa rhizospora*.

Dr. James Fletcher (*2*) mentions a fungous disease prevalent in the oak looper infestations on Vancouver Island. He says it attacked the insects in all stages of development. It was identified by Professor Roland Thaxter as *Sporotrichum globuliferum* Spegazzini.

Predators

Only one instance was noted of an insect feeding upon a looper larva. This was a Hemipterous nymph which has not been determined. Several instances were noted of large black wood ants dragging looper larvae along.

On July 8th, a young yellow warbler *(Dendroica aestiva* Gmelin) was discovered in a vine maple bush. The old bird was stuffing looper larvae down the young one's throat as fast as she could collect them. She only had to fly a few feet from her offspring to collect a billfull. The young one's capacity seemed unlimited, since it readily took all of the food supplied during fifteen minutes of observation.

On July 18th a junco *(Junco hyemalis oregonus* Townsend) was seen to eat looper larvae from a broad leaf maple.

On July 19th a number of chick-a-dees *(Penthestes rufescens?)* were observed for some time as they fed voraciously upon looper larvae. At least two other species of birds were seen to feed upon the larvae, one of which was apparently a kinglet and the other the white crowned sparrow *(Zonotrichia leucophrys* Forster). The above determinations were made from field observations only. It would be profitable, no doubt, to make an examination of the stomachs of various birds in an infested area.

Control by Airplane Dusting

At the present time airplane dusting offers the only feasible method of direct control of defoliators over large forest areas. Before discussing actual control operations it may be well to point out some of the problems to be considered in undertaking an airplane dusting project.

The first is, naturally, the selection of a suitable airplane. The choice must be governed largely by the character of the dusting project contemplated. In Ontario, a tri-motored plane, capable of carrying a pay load of 1,000 to 1,500 lbs., has been found much more satisfactory than a single motored plane or one of smaller capacity. If, however, the terrain is rough, with narrow canyons, a smaller type of plane would probably be less hazardous. In such cases it might be advisable to use several of the small planes to make up for the reduction in carrying capacity.

Another very important item is the selection of a landing field. Most flying concerns charge by the flying and waiting hour, and accordingly the flying bill varies directly with the distance to and from the landing field. The type of landing field also determines the type of landing gear the plane must carry. If on water, the plane must, of course, be equipped with pontoons.

Speed of execution is absolutely essential, aside from the fact that it reduces the cost, for good dusting weather is often of short duration and fullest advantage must be taken of it. Dusting of course cannot be done

in rainy weather or if there is a probability of rain within twenty-four hours. Greater success will be attained if there is no rain for at least one week after dusting.

Wind is another serious obstacle to good dusting. Although a side drift of four or five miles per hour is more desirable than so-called dead calm air, a wind of over ten miles per hour carries the dust too far from the line of flight, causing patchy, insufficient coverage. Ideal dusting conditions are present when there is a high humidity, dew on the foliage, and a side drift of three or four miles per hour, at right angles to the line of flight. The time of day when these conditions are present or approached varies with different localities. In some places, early morning hours are found to be the best, while some workers have found the evening to be better suited to the work. Careful consideration of weather conditions is therefore necessary and it is a good plan to keep in touch with the nearest weather station.

If possible, the plane should never fly more than fifty feet above the tree tops when dusting, and preferably about twenty-five feet. Under ordinary conditions, the flight lines can be 150 feet apart to obtain a coverage of eighteen to twenty pounds per acre. To accomplish this, the hopper must be regulated to deliver 375 to 400 pounds per mile.

On areas where there are no good guide lines already established to aid the pilot, it is sometimes necessary to mark out a base line by placing flags in the tops of trees at the beginning of every fourth flight line. It has been found that red or white flags are seen most readily from the air, the white being slightly better. The dusting strips are flown perpendicular to the base line. Ridges, streams, valleys, roads, power lines and shore lines may serve as guide lines upon which to base the lines of flight.

Even after the most careful plans have been made, and with the best of luck in the matter of favourable weather, a large part in the success of a project is due to the skill and judgment of the pilot. When possible, it is desirable to engage pilots with previous dusting experience. Problems are sure to arise, peculiar to each operation, which cannot be foreseen, and which must be dealt with as they are encountered.

Wigwam Inn Project.—The first airplane dusting project in British Columbia was undertaken in 1929 at Wigwam Inn, Burrard Inlet. There were several urgent reasons for doing this work. In the first place, it was advisable to demonstrate the feasibility of airplane dusting to timber owners and to the officers of the Provincial and Dominion Forest Services. It was realized that other infestations would probably appear and that all information possible should be obtained as to how to deal with them. Secondly, it was desirable to show the effectiveness of the calcium arsenate dust in killing the looper larvae. Thirdly, Wigwam Inn is a summer resort valued at not less than $100,000 and it was extremely desirable to preserve the scenic beauty of the immediate Inn surroundings, irrespective of timber values involved. All of those interested were frankly sceptical of the value of the dusting and consequently were unwilling to risk any large sums of money. It was therefore necessary to limit the project to a small experimental area of forty-five acres in the immediate vicinity of the Inn, in the hope that this timber would be carried through the peak year of feeding with a minimum of damage.

The type of plane used was a Boeing flying boat driven by a 420-horse power Wasp motor.

The dust used was commercial calcium arsenate, one part to six of hydrated lime. Twelve hundred pounds of dust proved sufficient to secure the desired coverage of 26 pounds per acre. The dust was put up in paper bags of 25 pounds each and shipped in barrels. These were stored in the basement of the Inn until ready for use. The basement is on the ground level and since the Inn is situated on the beach, it was not difficult to wheel the barrels down to the float fast enough to supply the plane during the operation.

The hopper used was 2 feet by 2 feet in cross section and 2 feet 10 inches high. It was constructed of galvanized sheet metal reinforced by heavier iron strips at the corners and tapered beneath to a round aperture 11 inches in diameter. An agitator was mounted 8 inches above the throat and consisted of an iron rod with several deep undulations. The outer end of the rod was fitted with a crank for hand operation. Release of the dust was controlled by a sliding gate. The hopper was placed inside the cabin of the plane and the dust released through the floor.

The stand of timber dusted is situated on the west side of the inlet, on a bench sloping gently back from the beach for 1,200 feet, after which the high mountains rise steeply. The composition of the stand has already been noted. It is mostly mature timber with a few old spike top cedars projecting above the general canopy level, making flying more hazardous.

Several causes contributed to delay the actual dusting operation. The weather was the main source of worry. The spring and early summer of 1929 were exceptionally rainy.

The first dust released was a trial load of 200 pounds delivered on the evening of July 30th. Weather conditions were good, calm with a slight southerly drift. On the following morning dusting was resumed at 8.30 a.m., and by 11.30 all of the dust had been delivered. At ten o'clock a slight breeze sprang up from the south which had increased to a velocity of about eight miles per hour by the time the dusting was completed. This materially aided in securing a better distribution. The cost of the operation was as follows:—

Hopper, material and labour	$ 52.92
Calcium arsenate, 1,400 lbs.	63.00
Express on dust	45.64
Freight, Vancouver to Wigwam Inn	9.00
Western Canada Airways	301.00
Total	$471.56

This cost should not be considered on a per acre basis, because the value of the timber, as such, was not involved. It must be remembered that this project was an emergency operation, organized and completed in less than one month.

After the dusting, the looper larvae had two full days of ideal feeding weather. It was clear, calm, and warm. On August 2nd the larvae commenced to drop from the trees in great numbers and the ground beneath severely infested trees was crawling with them. These showed the effects of poisoning, *i.e.*, sluggishness at first and later an apparent paralysis.

When the affected caterpillars fall the tendency is for them to climb again and in so doing hundreds died on the tree trunks and in great masses at the tops of stumps and snags. The counts shown in Table 4 were made beneath severely infested trees.

TABLE 4.—LARVAL COUNTS AFTER DUSTING

August 3—One sq. yd. beneath large maple	132 dead
August 3—One sq. yd. beneath large hemlock	51 dead
August 3—One sq. yd. beneath large hemlock	234 dead
August 5—One sq. yd. beneath large hemlock	354 dead
August 5—One sq. yd. beneath large hemlock	631 dead

These figures merely indicate that a great number of larvae were killed by the dusting but do not indicate the percentage of mortality. The estimation of the percentage of mortality after dusting is a difficult matter. Some of the methods used in the past are the following:—

1. Placing square yard pieces of cloth beneath branches and counting the number of dead larvae on them each day, both before and after dusting. Comparisons are then made with the number of live larvae which were on similar branches before dusting. This method is inaccurate because many of the larvae crawl considerable distances before dying and therefore crawl off the cloth.

2. Comparison of the number of live larvae shaken from twigs of similar size and under similar conditions before and after dusting. This method is also inaccurate because it assumes that the limbs compared were equally heavily infested, which may or may not have been the case.

3. A method which is fairly accurate for young even-aged stands is that employed in one dusting operation in Ontario. Four or five representative trees were delimbed over 20 foot square pieces of canvas both before and after dusting. All of the larvae were counted in each case and comparisons made. The main objection to this is that it is a slow and laborious process, entailing considerable expense and only suited to a particular type of stand. For most stands in the Northwest it is entirely out of the question.

It is thought that a better method might be worked out by placing square yard pieces of muslin stretched on frames at a number of representative situations on the area. A comparison of the density of the daily droppings might then be made for several days before and for two weeks after the dusting. The effectiveness of the dusting could then be calculated by the reduction in the amount. This method has been employed extensively in Europe.

Stanley Park Project.—In the fall of 1929, the presence in Stanley Park of adults of the western hemlock looper and the hemlock tip moth in considerable numbers indicated that heavy defoliation of the hemlocks would probably occur during the summer of 1930, unless control measures were undertaken. Defoliation was noted in a number of places in 1929, but not severe enough to kill any trees. A survey of the area was made in the fall of that year and the areas of defoliation indicated on the map. The situation was then presented to the proper city authorities and they were urged to undertake the dusting of the park in the spring of 1930.

The Western Canada Airways again undertook the contract to do the flying. Three Boeing flying boats were used, equipped with an entirely different type of hopper than the one used at Wigwam Inn. The arrange-

ment consisted of twin hoppers in the form of a saddle which fitted over the hull. The dust was discharged from both hoppers simultaneously and was released by means of a lever at the pilot's right hand. The pair of hoppers held 500 pounds of dust.

In order to insure as even a feed at the end of the delivery as at the beginning, a false bottom was put on the inclined side of the hopper, within. This was hinged at the bottom and a tension spring attached across the top. As the weight of the load decreased, the tension spring gradually pulled this panel into a vertical position so that all of the dust would be delivered and at a fairly even rate of flow.

Stanley Park occupies a peninsula of 1,000 acres but it was only necessary to cover 800 acres with dust. The stand consists of 70% hemlock, 20% Douglas fir, and 10% western red cedar. The tract is divided into smaller areas by trails and roads which served as excellent guide lines for the pilots, since these areas could be recognized from the air. The correct amount of dust for each area had previously been calculated and marked on the map.

Dusting commenced at 4 a.m. on June 15th. The entire supply of dust, gas, and oil had been loaded on to a scow the previous night. At 3 a.m. the scow was towed into Vancouver Harbour and located so that there was just room enough between it and the park for a good take-off and landing. The distance flown to and from the loading scow was thus minimized.

A tug was in attendance at all times so that the scow could be kept in proper position. The 50-pound bags of dust were placed around the edge of the scow against the uprights, in lots sufficient to fill each hopper. The planes flew in rotation as much as possible in order to facilitate loading and refuelling.

Officers of the Dominion Entomological Branch maintained communication with the pilots by means of a fast launch which travelled between the main park entrance and the scow. An automobile was kept at the entrance so that most parts of the park could be reached in a few minutes and the distribution of the dust checked.

Difficulties were increased by the number of spike top cedars which extend far above the general forest level. In some instances the pilots flew below these, skilfully avoiding them. This may not have been possible with larger machines.

The required eight tons of dust had been delivered by 10 a.m. Dusting conditions were ideal. There was very little wind, just enough drift to aid in securing a better distribution. During the early part of the dusting, the dew was quite heavy on the leaves, causing the dust to adhere very readily. The dust distribution was checked by examination of the leaves of deciduous trees beneath the conifers. The coverage obtained was from 18 to 20 pounds per acre. The cost of the operation was as follows:—

Western Canada Airways		$5,500.00
8 tons calcium arsenate		720.00
Freight on dust		144.00
Hire of Launch		30.00
	Total	$6,394.00

If based on the actual area dusted, the cost per acre was $7.96. The cost per acre of a similar project in Peninsula State Park, Wisconsin, in 1926, was $7.04. Barnes (*1*) gives an average cost per acre of $15.50 in dusting for the control of gypsy moth. Swaine (*4*) quotes an estimated cost of $6.00 per acre in dusting for the control of the hemlock looper in Quebec Province.

Seymour Project.—A similar dusting operation was carried out on the Seymour Watershed on June 19th. All of the flying arrangements were the same as described above, but the actual execution of the work was far more difficult because of the situation of the area.

Seymour Canyon is narrow, with steep walls, and is eight miles air line from tide-water. The length of the dusting strips was two miles. Each plane therefore flew twenty miles in delivering a load. There were thirty-two trips made, making the mileage flown to and from the area 640. About twenty-five miles can be added for taking off and reconnoitering and another twenty-five miles for turning, making a total of 690 miles flown. Dusting commenced at four a.m., and was completed at four p.m. Eight tons of dust were used.

The success of these two operations was gratifying to all concerned. It was estimated that in the case of the Stanley Park area, from 75% to 85% of the larvae were destroyed, and on the Seymour area, from 80% to 85%. Even under the most favourable circumstances it is extremely difficult to obtain a reliable mortality figure when the larvae are so small.

At the time of dusting the second moult had not occurred for the majority of larvae. The importance of this is apparent from the following considerations.

It had been previously noted that the emergence of the parasite, *Winthemia cilitibia* Rand, occurs between June 20th and July 20th, with the peak about July 11th. Observations in the field have shown that the majority of eggs are deposited after the third moult of the host. This occurs after July 7th for the majority of larvae. Therefore, if dusting is done during the later stages, many parasites are destroyed with the larvae, but if done during the early stages, before June 30th, the looper larvae are not only more easily killed, but the parasites later deposit eggs on those that escape the dust, and the natural increase of the parasite is not disturbed except by the limitation of food supply.

REFERENCES

1. Barnes, D. F. and S. F. Potts. Airplane Dusting Experiment for Gypsy Moth Control, Journ. Ec. Ent. *20*, 213-222. 1927.
2. Fletcher, James. The Vancouver Island Oak Looper Rept. of Entomology and Botany in Canada, Exp. Farms Rept., 175-177. 1893.
3. Fracker, S B Airplane Dusting to Control Hemlock Spanworm, Journ. of For. (U.S.) *26*, 12-23. 1928.
4. Swaine, J. M. Airplane Dusting Operations for the Control of Defoliating Insects. Canada Dept. of Nat. Defence, Rept. of Civil Aviat. and Civil Govt. Air Oper. for 1929. 1930.

Résumé

L'attaque de l'arpenteuse de la pruche de l'ouest, *Ellopia somniaria* Hulst, sur les conifères de la Colombie-Britannique. G. R. Hopping, Laboratoire fédéral de l'entomologie, Vernon, C.-B.

De 1928 à 1930, plusieurs foyers considérables de l'arpenteuse de la pruche de l'Ouest, *Ellopia somniaria* Hulst., ont été signalés sur le littoral de la Colombie-

Britannique. Une de ces invasions a été étudiée sur la Rivière des Indiens, le bras nord de l'anse Burrard. Les notes suivantes ont été prises sur le cycle évolutif de l'insecte:

L'insecte parfait fait son apparition et pond ses œufs en septembre. Les œufs éclosent le printemps suivant, vers la fin de mai ou le commencement de juin. Les larves sont actives entre la fin de mai et le commencement de septembre. La chrysalide, ou pupe, se voit entre le 10 août et le 10 septembre.

Cette arpenteuse est exposée, dans ses différentes phases, aux attaques de trois parasites diptères et de huit parasites hyménoptères Les plus agressifs de ces parasites sont les suivants: *Winthemia cilitibia* Rand., esp. *Hyposoter*, proche de *geometrae* Ash., *Amblyteles cestus* Cresson et esp. *Telenomus* proche de *dalmani* Ratz. Plusieurs espèces de champignons causent parfois une mortalité considérable et certains oiseaux de proie jouent également un rôle utile dans la répression du fléau. Les conditions de température entrent également en ligne de compte.

Un essai de saupoudrage par la voie des airs, démontrant que les moyens répressifs artificiels peuvent être utiles, a été conduit à Wigwam Inn, Burrard Inlet, en 1929. En 1930, deux opérations de saupoudrage par aéroplane, couvrant une étendue de 800 acres chacune, ont été conduites dans le Parc Stanley et sur le versant Seymour, d'où Vancouver reçoit ses eaux d'approvisionnement. Ces deux opérations ont réussi à enrayer l'invasion de l'arpenteuse de la pruche dans ces districts.

STUDIES OF SOLID STEM WHEAT VARIETIES IN RELATION TO WHEAT STEM SAWFLY CONTROL

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Sawfly injury to wheat in Western Canada is noticeable from the stems which apparently break off near the base and fall to the ground. The actual injury arises from the operation of the sawfly larvae which sever or partially sever the stems about one inch above the ground in preparation for their hibernation. Because of the existence of wheats with pithy stems the possibility of these in offering resistance to the activities of actual sawfly larvae has been studied.

Saskatchewan Provincial Statistics indicate that the damage to the wheat crop caused by sawfly is considerable and widespread. Estimates for the Marquis wheat area of Saskatchewan, which includes crop districts Nos. 1 to 7, show that sawfly damage for the years 1927 to 1932 averages 4% of the total yield, which is equivalent to a loss of about seven million bushels of wheat per year. The loss caused by sawfly damage in crop districts 3 and 4 for the same period is heavier than in others, being 5.5%. The damage is not evenly spread over the affected area. In some fields, or portions of fields, the grain is much more heavily infested than in others. Damage in some fields exceeds 50%, so that the loss sustained by individual farmers is often serious.

Marquis wheat appears to be highly susceptible to sawfly damage. Coupled with this is the fact that the greater portion of the Marquis wheat area is the natural habitat of the sawfly. These two factors together appear to serve to perpetuate the annual damage caused by the pest.

OCCURRENCE OF SOLID OR PITHY CHARACTER IN WHEAT

Nearly all the wheat grown in Western Canada possesses the hollow stem character. Stems of wheat varieties may be either solid, semi-solid or hollow. The solid character of wheat stems is generally regarded as referring to the presence of "pith" inside the stems. The amount of "pith" or the percentage of the wheat stem that is filled with "pith" varies with different varieties or strains. A hybrid between a hollow stem parent and a solid stem parent may produce intermediate types with stems which are partly solid and partly hollow. Biffen (*1*) crossed Turgidum (solid stem) and Vulgare (hollow stem) and found the F_1 stems to be hollow, but a splitting occurred in the F_2 generation in the ratio of three hollow to one "pithy" or solid. Engledow (*2*) reported similar results in 1923 with Polish (solid stem) and Kubanka (hollow stem) crosses, except that he found considerable variations of the pithy content in the F_3, F_4 and F_5 families. Stems that are filled with pith from the base of the spike to the crown of the root are said to be solid. Stems that are partly filled with pith and partly hollow are regarded as being semi-solid. The amount of pith found in semi-solid or intermediate types of stems can naturally vary quite widely, since a semi-solid stem may be less solid at only one part of

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an internode, or it may be filled with pith except in a small portion of an internode, usually just below the base of the spike.

Engledow (*2*) says: "It is to be expected that solidness of straw is not morphologically a simple character. Not only the presence of a greater or less amount of pith, but also the girth and other characteristics of the surrounding wall of the straw, must determine the relative solidness." These characteristics, together with other features peculiar to solid wheat stems, appear to offer various restrictive means by which reproduction of the wheat stem sawfly is considerably diminished or controlled.

Observations at Swift Current, 1929

A solid stem wheat such as Golden Ball and a semi-solid wheat as White Straw Tuscan, were not as seriously affected by sawfly injury as were the hollow stem varieties. Examination of solid stems indicated that, while some were infested, the sawfly larvae in most cases had destroyed only a small portion of the inner parts of the culm, and further, that the larvae did not penetrate the nodes of solid stems or solid portions of semi-solid stems in the direction towards the base of the plants. It may therefore be assumed that solid stem wheat varieties offer a possible means of controlling sawfly damage.

Control appears to be dependent on the following conditions:

(1) Would sawflies lay eggs in solid stem wheats?

(2) If the eggs were laid would they hatch and develop into normal larvae?

(3) If the larvae were trapped in the internodes of solid stems, could they be destroyed if the stubble, cut high by a header or a combine reaper thresher, were burned; or infested straw in stacks disposed of by the same means.

(4) Could the larvae sever the stems of solid stem wheat?

(5) Should the larvae in solid stem wheat reach the base of the plant, would their development be so impaired that they could not survive the winter?

EXPERIMENTS

Preliminary Tests, 1930.—Two heads of semi-solid wheat C.I. 7265-12, of Egyptian origin, were obtained from the United States Department of Agriculture for further tests. The seed was sown in two head rows in 1930. Many of the stems of the resulting crop were found to be hollow and infested with sawfly larvae. A number of solid stem plants were found and these were mainly unmolested. Heads from selected solid stem plants were used for increase of seed and further observation in 1931. Plants with solid stems, semi-solid stems and hollow stems were produced. Solid stem plants were only slightly damaged as in 1930.

Forced Infestation Tests, 1931.—In 1931, plants of Golden Ball and C.I. 7265-12 were caged and subjected to forced infestation, in order that all the plants in the cages would be subjected to sawfly attack. A large number of adult sawflies, previously hatched from wheat stubble, was placed in the cages at the normal egg-laying period for this purpose. The stems of the Golden Ball plants which were examined were found to be uniformly solid from the crown roots to the base of the spike and showed

only a slight infestation and complete immunity to severing by the sawfly larvae. Solid stems of C.I. 7265-12 were also very slightly infested. The hollow parts of semi-solid stems were considerably infested, but the downward movement of the larvae towards the base of the plant was invariably checked at the first node encountered in the solid, pithy part of the culm. Practically all of the hollow stems were severed at about one to two inches above the ground.

Forced Infestation Tests, 1932.—In 1932, seven varieties were subjected to forced infestation under cages. Solid or semi-solid varieties, were represented by Golden Ball and C.I. 7265-12 respectively. Marquis, Reward, Reliance, Hope and Ceres represented the hollow stem varieties. Adult sawflies, hatched out of Reward and Marquis wheat stubble, were introduced into the cages at the normal time of sawfly emergence. A large percentage of the stems of C.I. 7265-12 were hollow, and these were nearly all severed by the sawfly larvae, which, in some measure, accounts for the high percentage of damage as shown in Table 1. Most of the solid stems were only slightly damaged. Golden Ball, though infested to the extent of 18%, was resistant to severing. The Hope variety was only lightly infested with slight injury. Ceres also, shows little damage from sawfly, but it is known that this variety is of somewhat weaker straw than Marquis, and for that reason it is uncertain that Ceres may be regarded as strongly resistant to sawfly. The low percentage infestation of Ceres and Hope may be due to unsuitable development of the plants at the time of oviposition under unnatural forced conditions. Further observations are necessary to determine this point.

TABLE 1 —RESULTS OF FORCED SAWFLY INFESTATION OF WHEAT VARIETIES UNDER CAGES — YEAR 1932—DATA BASED ON EXAMINATIONS OF STEMS COLLECTED AT HARVEST

Variety	Stems not infested, %	Stems infested, %	Stems severed, %
B P.I. C.I. 7265-12, in small cage	25 2	74 8	53 9
B P I. C.I. 7265-12, in large cage	13 1	86 9	58 1
Ceres	92 8	7 2	2 1
Reliance	89 4	10 6	7 0
Reward	83 5	16 5	8 2
Marquis 10B	82 2	17.8	13.4
Hope	95 8	4 2	3 4
Golden Ball	82 0	18 0	Nil

Winter Survival.—To determine the percentage of winter survival of sawfly, and whether the character of the stems exerted any influence on the winter mortality of the larvae, samples of stubble from the seven varieties used in the 1932 Forced Infestation Test were gathered from each plot during the following spring and placed in metal containers under suitable temperatures to await emergence of the adult sawflies. Numbers of the stubbles examined, percentage of the stems found to be infected, the percentage of the stems actually cut by the larvae and the percentage that survived the winter are shown in Table 2. Though Golden Ball was infested 18% in 1932, no adult sawflies emerged in 1933. Emergence of

adults from 14.3 to 45% were obtained from all other varieties on this test. Thus, Golden Ball escaped heavy infestation, suffered very little damage by internal boring and severing of the stems and supplied no adults to continue the life cycle. Ceres and Hope, hollow stem sorts, produced a survival of sawfly larvae and emergence of adults equal to 14 3 and 18 8% respectively. Though the survivals from these varieties were considerably higher than that of Golden Ball solid stem which was nil, their percentages were also very much lower than all other varieties in the test.

TABLE 2.—INFESTATION AND WINTER SURVIVAL OF SAWFLY LARVAE IN STEMS OF CAGED WHEAT VARIETIES*, 1932-1933

Wheat—Variety	Number of stubbles examined	Per cent of stubble infested by *C. cinctus*	Per cent cut by *C. cinctus*	Per cent survival
B.P.I. C I. 7265-12, in large cage	282	70	57	30 4
B.P.I. C.I. 7265-12, in small cage	99	75	68	40 3
Ceres	102	28	6	14 3
Golden Ball	83	1	0	0
Hope	110	15	4	18 8
Marquis 10B	86	29	22	44 0
Reliance	101	20	11	45 0
Reward	98	29	16	28 6

* The percentage of the total number of stems, infested and cut by *C. cinctus*, was determined by actual examination of the collected stubble after emergence of the sawflies had been completed The percentage listed as cut is that of the total number of stems rather than that of the number infested

NATURAL INFESTATION TEST, 1932

Experiments with 38 Varieties or Strains of Solid Steam Wheats. —The 38 varieties or strains of solid stem wheat used in these determinations were obtained from Dr. O. Frankel, Lincoln College, Christchurch, New Zealand. Two of the varieties originated in New Zealand, the remainder were obtained by the Lincoln College from Spain, Portugal and Morocco. All the 38 varieties were subjected to natural infestation. In addition to examining the stems for sawfly damage, 250 stems of each variety were examined to determine the extent of the solid character and pithiness of the stems (See Table 3). For convenience, the extent of pithiness was determined by using the nodes as an index. Stems, solid from the ground to the first node above ground, were listed in the first node column. Stems, solid to the second node, were listed in the second node column and so on. In addition, the number of stems infested was noted for each "node" group. A high percentage of all the varieties were solid to the fifth node, which indicates that the stems were entirely solid from the roots to the spike. The percentage of infestation was also low for many of the varieties. The percentage severed was from nothing to slight for all the varieties. Varieties S-378 and S-835 had a large percentage of hollow stems. These were found to have very thick walls, which was regarded as the probable reason why these varieties were not more severely infested or severed. Marquis wheat, and other hollow stem varieties sown at the same time, were considerably damaged by sawfly.

TABLE 3—SOLID STEM CHARACTER OF WHEAT IN RELATION TO SAWFLY INFESTATION AND DAMAGE

ROD-ROW TEST PLOTS OF WHEAT VARIETIES INTRODUCED FROM NEW ZEALAND

DATA BASED ON EXAMINATION OF 250 STEMS

All Varieties subjected to Natural Means of Infestation

S C Ac. No	Variety No	Number of stems showing solid character from the crown to the various nodes and the number in each group infested by sawfly larvae												Total stems not infested, infested or severed out of 250 stems examined					
		Stems hollow throughout		1st node		2nd node		3rd node		4th node		5th node		Number of stems not infested	Number of stems infested but not severed	Number of stems infested and severed	Per cent infested	Per cent severed	Remarks
		Hollow	Infested	Solid	Infested	Solid	Infested	Solid	Infested	Solid	Infested	Solid	Infested						
350	Solid Straw	—	—	—	—	—	—	4	—	4	—	242	8	242	7	1	3.2	0.4	
352	Tuscan S—373	—	—	—	—	—	—	14	—	16	—	220	22	228	20	2	8.8	0.8	
353	S—374	—	—	1	—	2	—	10	—	20	—	217	6	244	5	1	2.4	0.4	
354	S—377	3	2	3	—	7	—	74	5	133	20	30	—	223	25	2	10.8	0.8	Very thick walls.
355	S—378	130	8	58	—	19	10	37	—	6	1	—	—	231	19	—	7.6	—	
357	S—386	3	2	5	—	3	—	25	3	61	12	155	13	220	28	2	12.0	0.8	
359	S—493	—	—	—	—	6	—	4	—	5	—	235	2	248	2	—	0.8	—	
361	S—615	—	—	—	—	1	—	3	—	2	—	249	4	246	4	—	1.6	—	
362	S—617	—	—	1	—	5	—	25	—	34	3	185	30	217	28	5	13.2	2.0	
363	S—618	6	—	5	—	5	—	4	—	11	—	219	45	205	45	—	18.0	—	
364	S—630	—	—	—	—	—	—	2	—	17	—	231	22	228	22	—	8.8	—	
365	S—632	1	—	—	—	—	—	2	—	4	—	243	1	249	1	—	0.4	—	
366	S—663	3	1	—	—	1	—	8	—	2	1	236	20	228	22	—	8.8	—	
367	S—635	—	—	—	—	1	—	6	—	19	4	224	39	207	34	9	17.2	3.6	
368	S—639	—	—	—	—	—	—	5	—	5	—	240	55	195	55	—	22.0	—	
369	S—668	—	—	1	—	—	—	3	—	10	1	236	1	248	2	—	0.8	—	
370	S—671	2	—	—	—	1	—	8	—	41	7	198	34	209	41	—	16.4	—	
371	S—673	—	—	—	—	—	—	4	—	105	37	141	9	204	40	6	18.4	2.4	
372	S—683	—	—	—	—	—	—	1	—	3	—	246	60	190	43	17	24.0	6.8	
373	S—684	1	—	—	—	—	—	3	—	4	—	242	87	163	80	7	34.8	2.8	
374	S—691a	—	—	—	—	9	—	14	—	3	—	224	14	236	14	—	5.6	—	

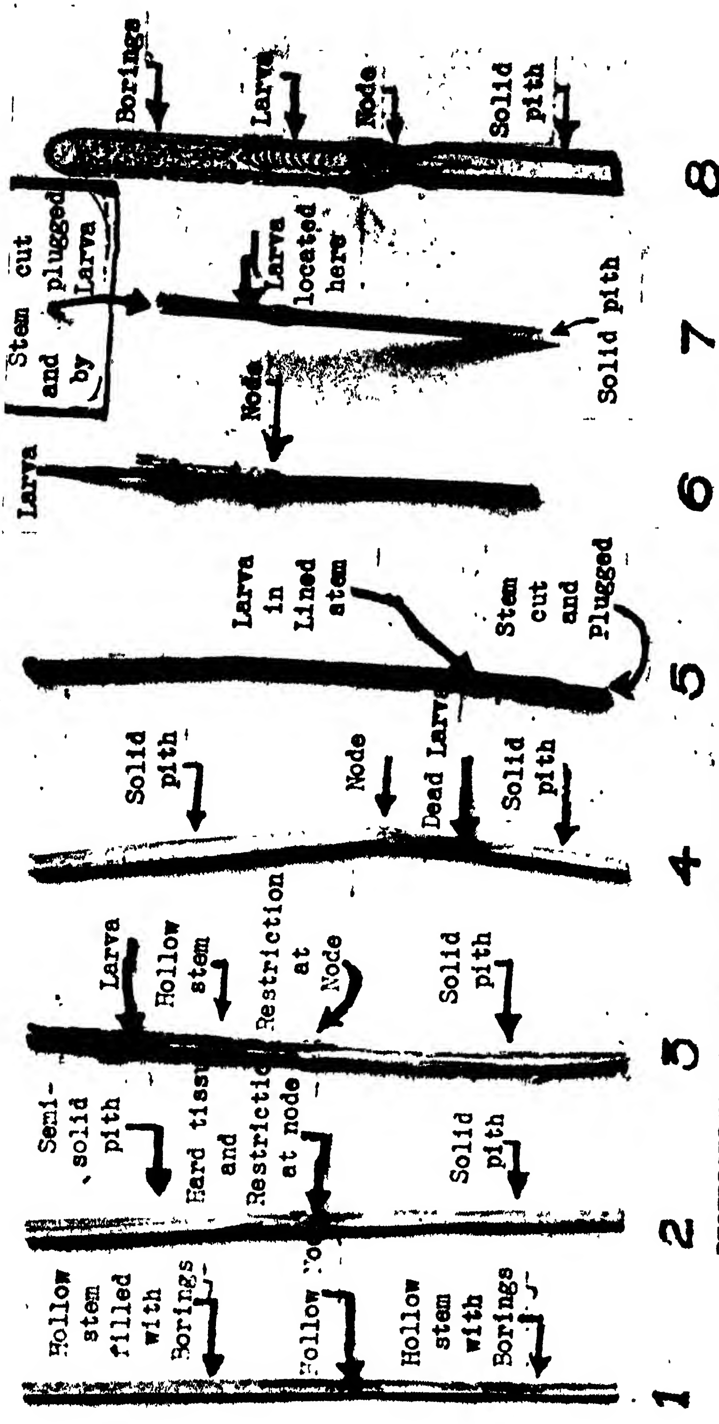
374	S—691b	7	—	11	—	4	—	20	2	11	—	197	10	238	10	2	4.8	0.8	
*374	S—691c	5	—	1	—	6	—	11	—	6	—	41	5	65	4	1	7.1	1.4	
†374	S—691d	3	—	—	—	—	—	4	—	—	—	43	4	46	4	—	8.0	—	
375	S—700	—	—	—	—	—	—	3	—	17	—	230	8	242	7	1	3.2	0.4	
376	S—702	—	—	—	—	1	—	1	—	17	3	231	34	213	36	1	14.8	0.4	
377	S—707	—	—	1	—	10	—	217	37	15	—	7	—	213	37	—	14.8	—	
378	S—717	—	—	—	—	—	—	2	—	—	—	248	93	152	81	17	39.2	6.8	
379	S—736	—	—	—	—	3	—	28	4	160	2	59	—	244	6	—	2.4	—	
380	S—767	—	—	1	—	3	—	15	—	81	39	150	18	193	54	3	22.8	1.2	
381	S—771	—	—	—	—	1	—	2	—	—	—	247	1	249	1	—	0.4	—	
382	S—778	—	—	—	—	—	—	15	—	35	5	199	26	219	29	2	12.4	0.8	
383	S—802	20	20	1	—	20	—	43	2	49	—	117	3	225	24	1	10.0	0.4	
384	S—804	—	—	—	—	—	—	37	—	74	13	139	2	235	15	—	6.0	—	
385	S—834	4	—	5	—	10	—	61	—	75	18	145	—	232	12	6	7.2	2.4	Very thick walls.
386	S—835	246	45	4	—	—	—	—	—	—	—	—	—	205	44	1	18.0	0.4	
387	S—895	—	—	—	—	—	—	35	1	204	6	11	0	243	7	—	2.8	—	

* Data based on 70 plants examined
† Data based on 50 plants examined.

More recent observations in the examination of over 10,000 culms from 38 solid stem varieties, show that the larvae seldom succeeded in boring through the node. The wall of the culm at the nodes of the solid stem varieties was found to be thicker than those of hollow stem varieties such as Marquis. Also, the inside diameter of the culm at this point was considerably reduced and the pith adjoining somewhat denser, thus providing considerable obstruction to the downward or upward travel of the larvae. The movement of the larvae, therefore, was confined mainly to one internode and usually only portions of the solid internodes were affected. Further, only a few of the infested stems were cut by sawfly. When examining stems in the laboratory, it was frequently found that the living larvae were lodged above the first, second or even third node. The larvae had apparently found it impossible to pass the node and reach the base of the stem, their normal over-wintering position. Portions of these solid stems showing the larvae just above the nodes are to be seen in the accompanying plate, Figure 1. Stem No. 1 is an infested hollow stem of Marquis wheat. The node appears hollow as well as the internodes. Although the aperture at the node is slightly reduced, the movements of the larvae were apparently not hindered. Stem No. 2 is semi-solid or almost completely filled with pith above the node. The lower internode is solid or completely filled with pith with the exception of a small cavity just below the node. The distance between the inner walls of the culm becomes much smaller at and through the node. The cell tissue at this point is also hard. The restricted passage, together with the hardened cell tissue, appeared to be quite effective in resisting the efforts of the larvae to bore through. Stem No. 3 shows the larva, which was found alive in December at the time of examination of the stem Borings show that it had travelled as far as the node where apparently it could make no further progress. In stem No. 4 an egg was laid and hatched in a small cavity below the node of a solid stem. The larva developed partially and died. Stem No. 5 is semi-solid and was severed by the larva just above the node and plugged at the lower end, which is unusual. Stem No 6 is cut away at the top to expose a larva which had lined the stem just above the node to establish its wintering quarters at that point. Stem No. 7 is similar to that of No. 6. The stem was cut and plugged by the larva three fourths inch above the centre of the node. The stem below the node is filled with solid pith. The larva is expected to be located between the plugged end and the node The sketch at No. 8 illustrates the apparent resistance offered to sawfly larvae movements by the decreased opening through the node, together with the accumulation of hard cell tissue at that point.

CONCLUSIONS

Observations and experiments at the Dominion Experimental Station, Swift Current, indicate that sawfly damage might be reduced to proportions of little consequence by the use of solid stem varieties of wheat. The solid stem varieties of wheat, however, should include kinds that are of good milling and baking value suitable for bread making purposes. Since varieties of *Triticum vulgare* with solid stems are available, the breeding of desirable solid stem high quality bread wheats is not an insurmountable obstacle.



RESTRICTION OF SAWFLY LARVAL MOVEMENT AT NODES OF SOLID STEM WHEAT

1. Infested Hollow Stem
2. Solid Stem Showing Node Restriction
3. Larva Arrested by Node Restriction
4. Dead Larva in Small Cavity below Node
5. Larva in Stem Severed above Node
6. Larva Trapped in Stem above Node
7. Larva Trapped above Node & below Plug
8. Sketch - Larva Movement Stopped at Node

FIGURE 1

ACKNOWLEDGMENTS

The writer wishes to acknowledge the interest and helpful guidance throughout the work of Mr. J. G. Taggart, formerly Superintendent, Dominion Experimental Station, Swift Current; also the practical help of Mr. Chester Smith, Entomologist in Charge Sawfly Parasite Investigations at Swift Current, who conducted hatching work. Thanks are extended also to Mr. H. L. Seamans, Entomologist in Charge Entomological Laboratory, Lethbridge, Alta., and to Mr. S. Barnes, Field Husbandman, Dominion Department of Agriculture, for the kindly consideration in reading the manuscript.

REFERENCES

1. Biffen, R. H. Mendel's laws of inheritance and wheat breeding. Jour. Agr. Sci. *1*. 1905-06.
2. Engledow, F. L. The inheritance of glume length in a wheat cross. Jour. of Gen. *13*; p. 94. 1923.
3. Criddle, Norman. The western wheat stem sawfly and its control. Dom. Dept. of Agr. Bull. No. 6, New Series.
4. Secretary of Statistics. Ann. Rep. Dept. of Agr. of the Prov. of Saskatchewan. 1927-1932 inclusive.

Résumé

Etudes des variétés de blé à tige solide au point de vue de la répression de la mouche à scie de la tige du blé. H. J. Kemp, Station expérimentale fédérale de Swift Current, Sask.

Les observations et les expériences qui ont été faites à la Station expérimentale fédérale de Swift Current indiquent que l'on pourrait réduire peut-être à un minimum de peu d'importance les dommages causés par la mouche à scie de la tige du blé si l'on se servait de variétés de blé à tige solide. Il faudrait cependant que ces variétés de blé à tige solide comprennent des espèces qui ont une bonne valeur meunière et boulangère, qui sont bonnes pour la fabrication du pain. Comme il existe des variétés de *Triticum vulgare* à tige solide, la production de blé à pain à tige solide de haute qualité ne pourrait pas être un obstacle insurmontable.

UNDULANT FEVER AND THE DAIRY INDUSTRY

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The need for active and intimate co-operation between all fields of science and between science, producers, and the purveyors of food is essential for the ultimate control of many of our most stubborn human diseases. Among the numerous examples of such effort is the combat against that long and universally feared disease—tuberculosis. Efforts to control this "white plague" would be of little or no avail were it not for the complete co-operation of the milk producer with the veterinarian, the veterinarian with the bacteriologist, the bacteriologist with the hygienist, the hygienist with the medical doctor and the municipal or political authorities. Robert Koch, the discoverer of the tubercle organism, considered at one time the organism of bovine origin to be incapable of initiating the disease in the human; little doubt of this fact now remains.

It took twenty-one years to observe that the organism isolated by Bernard Bang of Denmark and named *Bacillus abortus* was similar in its basic characteristics to the etiological factor Malta fever; and it has taken another sixteen years to demonstrate that the organism considered by Bang to be the etiological factor of infectious abortion in cattle is also pathogenic for man. Although, unlike the tubercle organism, *Brucella abortus* does not manifest a similar clinical picture in each host, there remains little doubt that it can initiate human disease.

In Canada and in the United States, the disease in humans caused by the abortus organism is known as "undulant fever." The mode of transmission of the organism from animal to human is again somewhat comparable to that of the tubercle organism, viz., by infected milk. Because of this, we are dealing with a problem which directly concerns both the consumer and the producer.

Infectious Abortion

Bang's organism, now known as *Brucella abortus*, was discovered in 1896. Since that time an immense amount of work has been carried on in an attempt to subdue or control infectious abortion in cattle. The attempts to cure or to immunize animals against the disease have been sadly unsuccessful, and the malady must still be classified as "incurable." That the disease in cattle is now world-wide is evidenced by reports from every country where cattle raising or dairying is practised.

The presence of *Brucella abortus* in the milk of cows was first foreshadowed in 1899 by Theobald Smith of the United States Bureau of Animal Industry; his observation has now been amply confirmed by both the guinea pig inoculation and the direct Petri-plate methods. Sufficiently serious is the dairyman's loss of valuable foundation stock and the resultant diminished milk supply; but still more serious, more far-reaching, is the medical aspect—the relation to undulant fever in the human.

To make the question still more perplexing, it has now been shown by experiment that *Brucella abortus* is transmissible to dairy products such

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as butter and ice cream, and is viable in these products for a period longer than the average holding time.

Malta and Undulant Fever

The general features of Malta fever (Mediterranean undulant fever), with its long-drawn pyrexia, characteristic recrudesence, associated splenic enlargement and low mortality, have been familiar for many years along the Mediterranean littoral. The history of the disease affords an excellent example of a bacterial disease, the control of which was not immediately affected by the discovery of its causative agent. While Surgeon David Bruce, a British Medical Officer, reported the discovery of the organism causing fatal cases in the soldiers stationed on the Island of Malta, in 1887, the mode of infection remained obscure until 1905, when Dr. Zammit found the organism in goats.

Since goats' milk was used by the British troops at Malta, it was immediately suspected of being the carrier of the disease germ to the human. Steps were taken by the British Army and Navy to stop the supply of goats' milk to the troops at Malta, and this resulted in the almost complete eradication of the disease on the island within one year. The disease in that locality became known as Malta fever. Bruce, considering the organism a coccus, named it *Micrococcus melitensis*. It is now known that the observation of the discoverer was incorrect and that the organism is rod-form. In honour of Bruce, this and related organisms are now classified under the genus *Brucella*—the organism found by Bruce as *Brucella melitensis*, that found by Bang as *Brucella abortus*, and another found by Traum, in hogs, as *Brucella suis*. It is now a well established fact that all three species of Brucella are pathogenic for human beings. Data in support of this fact have come from workers in North and South America, the British Isles, and many European countries.

Kennedy (*1*) in 1914 showed that agglutinins for *Brucella melitensis* were sometimes present in the milk and serum of cows in England, and was the first to suggest that undulant fever might be of bovine origin.

The interesting observation that the organism which had caused Malta fever in the British troops was identical with the much-studied organism responsible for infectious abortion in cattle was made by Alice Evans in the United States in 1918. The above observation immediately directed attention concerning the cause of cases of undulating fevers in North America in persons who had no direct or indirect contact with goats, but who lived on farms where infectious abortion of cattle was prevalent. Suspicions that the organism causing infectious abortion in cattle might be pathogenic to the human became fact when, in 1924, Dr. Keefer, of Johns Hopkins Hospital in the United States, reported the isolation of *Brucella abortus* from a case of undulating fever.

The disease caused by *Brucella abortus* is now termed undulant fever. The clinical course of undulant fever caused by *Brucella abortus* infection is, as a rule, milder than that of Mediterranean undulant fever. The patient develops a continued remittent fever, lasting for some weeks and falling by lysis, but sometimes followed by one or more relapses. The duration of the febrile period is very variable, lasting for a few weeks up to many months. The fever is accompanied by headache, loss of appetite,

weakness, a tired feeling, sweating and wasting. The pulse is relatively slow. The blood frequently shows a slight leucopaenia, with a relative lymphocytosis. The spleen, and often the superficial glands, may be enlarged, and joint and muscular pains are common. The clinical symptoms are in many ways comparable to those of rheumatic fever, and there is evidence to indicate that in this country Brucella infections are sometimes incorrectly diagnosed as rheumatic fever.

Undulant Fever in Canada

The first report of undulant fever in Canada was by Harris (*2*) in 1928. Since that time, cases have been reported sporadically from every province of the Dominion except Prince Edward Island. Hardman (*3*) reports that in Ontario alone 225 cases have been reported within a two-year period. The disease exists in Quebec, with an incidence of cases which is not yet determined. The Provincial Bureau of Health in co-operation with Macdonald College is now making a concentrated effort to gain more information on the prevalence of the infection and the modes of transmission of the causal organism. There is little doubt that human infections with *Brucella abortus* exist to a much greater extent than has previously been considered. Dible (*4*) points out that some 20% of cases of undulant fever fail to show agglutinins. If we summarise the epidemiological and experimental evidence, we see that undulant fever must now be clearly recognized as a widespread infection, which in a very large proportion of cases is evidently carried by the bovine species. In the United States it appears that swine are also important agents in the transmission of the etiological factor. Apart from the clear clinical cases of the disease, there is also abundant serological evidence of the occurrence of mild infections and subinfections. In some cases these infections appear to result in vaccination and immunization, a converse condition of affairs to that which holds for true Malta fever.

There is evidence to show that the pathogenicity of *Brucella abortus* for the human is increasing. It has been stated by Hall (*5*) that "undulant fever prevalence may be on the up curve, potentially at least. If nothing is done to control the disease a great endemic wave of this ailment among men, in the not too distant future, is a catastrophe which is well within the realm of the possible." In the opinion of the author, two factors are now influencing the reported increase of undulant fever in Canada: first, the recognition of the infection because of more complete clinical information concerning the disease; and, second, a steady increase of virulence of the organism. It is a well known fact that the pathogenicity of certain organisms increases and decreases to form definite cycles. It is possible that at the present time we are on the phase of increasing virulence of the *Brucella abortus* cycle. Just what degree of virulence the organism may reach must be left to presumption.

That *Brucella abortus* is concerned with the etiology of undulant fever in Canada has been revealed by the recent work of Thompson (*6*), who has succeeded in isolating the organism from two cases of undulant fever in the province of Quebec. So far as the author is aware, this represents the first isolation from a case of undulant fever in Canada of an organism exhibiting the peculiar carbon-dioxide requirements of *Brucella abortus.*

In one case the organism was also isolated from the milk supply used by the patient; the two organisms were compared, and little doubt remains regarding their identity. Gilles (7) has shown that in France cattle are frequently infected with the *melitensis* strain of Brucella and that, while a certain number of cases were infected through drinking milk from infected animals, the etiological agent did not exhibit the peculiar properties of *Brucella abortus*.

Based on the evidence that few goats are maintained in Canada, and that the organisms isolated from infected animals in Canada are always the *abortus* and not the *melitensis* strain, it is unlikely that the *melitensis* strain plays an important role in the etiology of undulant fever in this country.

Methods of Control

Unfortunately, there is at present no effective prophylactic treatment; the treatment is symptomatic. The mortality rates from undulant fever appear to be somewhat higher in Canada than in other countries. Hardman (3) reports a case fatality rate of 6 6%; Hardy (8) considers the mortality rate in United States to be about 3%; Dible (4), who has made an extensive survey of mortality rates of the disease, states that the mortality is low but definite, being about 2 to 3%. Owing, however, to the limited amount of definite data on this question, the above figures may be somewhat misleading. While the mortality rates may not be high, the disease, because of the excessive temperatures produced and the long disability period (sometimes six months), should be considered to be of paramount importance in public health administration.

Effect on the Dairy Industry

According to the foregoing information, the reader may well judge for himself the future course of the dairyman. That infectious abortion (Bang's disease) in dairy cattle is widespread in Canada is evidenced by reports from veterinarians and farmers from every province. Watson (9) based on data compiled from results of serological tests carried out two years ago, estimates about 20% infection. No statistics are available to show the relative infection in the various provinces. Dr. R. L. Conklin, technical adviser to the Veterinary Service for the Province of Quebec, presents figures to indicate 12% infection in the province. It has been shown by Gwatkin (*10*), and also by Thompson (*11*), that *Brucella abortus* is eliminated with the milk of a high percentage of cattle reacting to the blood test in dilutions of 1 : 100 or higher. Pasteurization will render milk safe from the viewpoint of undulant fever; this method of protection appears very simple, and rightly so, for well organized towns and cities in so far as direct milk consumption is concerned, but is quite impractical for rural communities.

The transmissibility of *Brucella abortus* from milk to dairy products is an important problem from the dairyman's viewpoint. It is neither convenient nor practical to pasteurize milk for the production of cheese; few farms, indeed, are equipped to effectively pasteurize the cream used in the home manufacture of butter or of ice cream. The question of "certified" and "special" milks are causing much concern to public health

authorities. These milks are *not* pasteurized. Few herds producing certified milk are at the present time free from infection with *Brucella abortus*. The organism has been isolated from certified milk in Montreal. Are public health authorities entirely justified in allowing the consumer to believe that, because he pays a higher price for certified milk, he is receiving a product which is safe for his family?

Attempts are already being made to eradicate the disease in cattle. Because of the widespread nature and the frequency of the disease in Canada, the reader may easily visualize the difficulties confronting such an undertaking. Any system of wholesale slaughter seems prohibitive at the present time. It has been shown that although cattle may show no clinical symptoms of infection, they may be "carriers" and may eliminate the organism with the milk. The province of Ontario is making an effort to eradicate *Brucella* infection in prescribed areas and seems to be meeting with encouraging results. This action will result in a two-fold benefit to the farmer; it will not only insure that his milk supply is safe for human consumption, but also will enable him more advantageously to dispose of his surplus stock.

The first step in the successful control of an infectious disease is to understand the disease biologically. The most important biological fact in connection with an infectious disease is its causative agent. While our knowledge of the microbial cause of undulant fever has developed significantly during the past few years it is certainly not complete: suffice it to say that recent findings of workers in Canada, United States, Great Britain and European countries incriminate *Brucella abortus* as the cause of an appreciable number of cases of undulant fever. We are just beginning to realize the importance of the disease in Canada. It is an established fact that we have in our country a great many dairy cattle infected with *Brucella abortus* and that the organism is frequently eliminated with the milk. It has been pointed out that statistics do not show a high co-relation between the consumption of raw milk and the incidence of undulant fever, but on the other hand, people who contract undulant fever are usually drinkers of raw milk. There are several logical reasons to explain the present low incidence of the disease. It must be borne in mind that the incidence is on the up-curve. The most satisfactory method of control lies in prevention. The co-operation of the producer, the veterinarian, the physician, and the public health authorities is needed to combat undulant fever successfully.

REFERENCES

1. KENNEDY. Jour. R.A.M.C. *177* : 2. 1914.
2. HARRIS, N. Can. Pub. Health Jour. *19* : 272. 1928.
3. HARDMAN, R. P. Can. Pub. Health Jour. *24* : 347. 1933.
4. DIBLE, H. Recent advances in bacteriology, 2nd Edn. P. Blackiston's Son & Co. Inc., Philadelphia. 1932.
5. HALL, M. The National Health Review 1 : 56 1933.
6. THOMPSON, REDVERS. Can. Med. Ass'n. Jour (In print).
7. GILLES, M., REV. General de Med. Veterinarire, *41* · 476. 1932.
8. HARDY, A. U. U.S. National Inst. of Health, Bul. 158 : 63. 1930.
9. WATSON, E. A. Personal communication, February. 1934.
10. GWATKIN, R. Report: Can. Pub. Health Ass'n. Meeting, Toronto. 1933.
11. THOMPSON, REDVERS. Ph.D. Thesis, McGill University (unpublished). October. 1932.

Résumé

La fièvre ondulante et l'industrie laitière. R. Thompson, Collège Macdonald, P.Q.

Il ressort de certaines enquêtes qui ont été conduites tout récemment au Canada sur l'existence de la fièvre ondulante et de l'avortement infectieux (maladie de Bang), que ces maladies se rencontrent dans notre pays en proportion beaucoup plus grande que l'on ne s'imagine généralement. Les cas de fièvre ondulante chez l'homme augmentent sans cesse et près de vingt pour cent des troupeaux laitiers sont affectés d'avortement épizootique. Le *Brucella abortus*, l'agent étiologique de cette maladie, chez l'homme aussi bien que chez les animaux domestiques, peut se transmettre au beurre et à la crème glacée. Il semble que la virulence de cet organisme augmente.

Les tentatives que l'on a faites en ces trente dernières années pour extirper l'avortement infectieux des troupeaux de bovins ont complètement échoué. On ne connaît pas encore de traitement satisfaisant pour la fièvre ondulante. Il est donc tout à fait évident que nous devons chercher les moyens de prévenir l'infection plutôt que de chercher à guérir la maladie après qu'elle s'est établie. Ce n'est que par l'union complète des efforts entre le laitier, le médecin et le consommateur que nous pouvons espérer combattre les ravages de l'infection du Brucella dans notre pays.

CANADIAN ACCESSION SYSTEM FOR CEREAL CROPS

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Until 1933 cereal workers and plant breeders in Canada had no system of accessioning varieties outside of the particular institutional systems. This state of affairs was not only confusing but far from satisfactory, particularly when articles were published or the performance data on a group of varieties were compared. If by chance the varieties possessed the United States Bureau of Plant Industry C.I numbers some help was given, but in many cases varieties in Canada do not possess this means of identification and consequently an element of uncertainty was introduced when varieties could not be clearly traced to their origin Further confusion was caused when these varieties became available to the general grower

At the Plant Breeders meeting of the Canadian Seed Growers' Association, held in Winnipeg in 1929, the question of the need of a wholly Canadian system of accessioning was introduced for discussion and possible action. The general opinion was strongly in favour of a suitable system, and a small committee composed of Dr. L. E. Kirk and J. G. C. Fraser was instructed to bring in a report and recommendations at the next meeting of the Plant Breeders Committee

After corresponding with the various institutions using accession systems, both in America and abroad, and after a careful study of these systems, the committee recommended a comparatively simple system based partly on the United States Department of Agriculture Bureau of Plant Industry system and partly on the best points taken from the other systems investigated.

The report was accepted and the Cereal Division, Central Experimental Farm at Ottawa, was given the task of getting the work under way. All agricultural institutions, both Provincial and Federal, were circularized and asked to co-operate by sending in a list of the cereal crop varieties they wished to have listed in the new system, which has been designated "The Canadian Accessioning Number System".

Due to delays of one kind or another, the listing of the varieties was not completed until July, 1933, when a progress report was presented at the Plant Breeders meeting held in Regina. In January, 1934, mimeograph copies of the lists of all the varieties of wheats, oats, barleys, flax and beans were completed and mailed to those co-operating. The work will continue and, periodically, supplementary lists will be published.

It is interesting to note that, in the August issue of this magazine, Dr. O. S. Aamodt, of the Univeristy of Alberta, in his article entitled "Resistance of wild oats and some common cereal varieties to freezing temperatures" has made use of the new accessioning system. This is the first published article in which the Canadian Accessioning Numbers (C.A.N.) have been used and it is suggested that Canadian agronomy workers should make use of this accessioning system as far as possible, in order that references to seed stocks of varieties grown in Canada may be readily traced.

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A MALADY OF THE POTATO IN ALBERTA SIMILAR TO PSYLLID YELLOWS[1]

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[Received for publication May 22, 1934]

There is in Alberta a malady of the potato which appears to resemble closely psyllid yellows, recently described by Richards and Blood (*1*), and said by them to be destructive in Utah, U.S.A., and present in certain neighbouring states. They found the malady to be associated with the feeding on the vines of nymphs (only) of *Paratrioza cockerelli* Sulc. As to its seriousness, they state: "Psyllid yellows, in its effect upon the plant, must be ranked among the most destructive of known potato diseases." When the plant is attacked during early stages of tuber formation, no crop results, and early death of the plant frequently ensues. They also state: "The symptomology of psyllid yellows varies greatly with the number of insects feeding, the length of feeding period, and the intensity and duration of light exposure during the time of feeding", and further: "Psyllid yellows is systemic and affects the form and physiology of the entire plant".

Each year from 1919 to 1922, inclusive, in 1924, and from 1927 to 1933, certain potato plants here and there in central Alberta have developed rather consistent symptoms, which suggest a type of disease different from others known here. Affected plants develop naturally for a time, then become more or less abnormal. Most common is a slight to definite swelling of the nodes, lengthening of the internodes in some plants, and a shortening of them in others, deformed axilliary branching, with aerial tubers in certain severe cases, and, as a rule, few to no tubers develop. Usually plants are more or less stunted or rangy in appearance, and the leaves more or less rolled. Frequently affected plants resemble severe cases of the disease caused by *Rhizoctonia Solani.* These have extensive axilliary branching and aerial tubers, and the roots and stem-parts below the ground are without lesions of any kind. The photograph of one of these plants, which appears in Figure 1, A, is not unlike a type shown by Richards and Blood in their text Figures 3, B, and 4, D (left). While such cases are not uncommon, the type most frequently found is that without pronounced axilliary branching or aerial tubers (Figure 1). With the exception of the Medicine Hat case, presently referred to, affected plants so far observed do not occur in close proximity, but here and there in the field.

The Medicine Hat case just mentioned was an outstanding exception, in point of severity and in its epidemic nature, to what has been described, but not essentially different in gross symptoms. Affected plants, fresh from fields of central Alberta, were compared with those from Medicine Hat in southern Alberta, and the symptoms on many plants appeared to be identical. Many plants of the Early Ohio variety from Medicine Hat exhibited the odd, bushy, and tuft-like second growth from the stalks identical with the photograph of plants shown by Richards and Blood in

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A. Vines of Cobbler variety with pronounced deformity, shortened internodes, and no tubers. B. Vines with symptoms intermediate to "A". C. Tuft-like second growth and rolling of leaves of affected Early Ohio vines from the Medicine Hat case (see text).

Figure 5, C, of their paper, and reproduced here, by their courtesy, in Figure 1, C. They stated that this type of growth is a characteristic peculiar to Early Ohio affected with psyllid yellows.

Over 100 acres in a local area in and about Medicine Hat in 1932 were a total failure. Early Ohio and Bliss Triumph failed to recover, and even small tubers were extremely scarce. Certain late varieties made some recovery late in the season. Tomato plants nearby were affected similarly. The malady was not observed in the same area in 1933.

In order to ascertain whether progeny from affected potato plants would transmit the symptoms, tubers from 20 plants of the Medicine Hat case (including all varieties affected), and from 40 plants obtained near Edmonton, in north central Alberta, were planted at Edmonton in 1933. The progeny and plant from each tuber were apparently normal in every respect. Richards and Blood found that tubers from affected plants did not appear to transmit the disease.

The Medicine Hat case was not reported until late in the season, but the general nature of attack at that time strongly suggested insects had been involved. Mr. E. H. Strickland, Professor of Entomology, University of Alberta, kindly informed me that, in 1928, tomato plants grown in a greenhouse at Medicine Hat were severely infested with a psyllid which resembled *P. cockerelli*, but which could not be determined with certainty. He also states: "A few psyllid nymphs have been found on the leaves of potatoes which were growing in this district. Four species of this family are known to occur in Alberta, but *P. cockerelli* has not been definitely recorded from the province."

Whether all these symptoms described herein were caused by *P. cockerelli*, or by other insects, or agents, has not been determined. However, there appear to be many points of close similarity with the psyllid yellows described by Richards and Blood.

REFERENCE

1. Richards, B. L., and H. L. Blood. Psyllid yellows of the potato. Journ. Agr. Res. *46*: 189-219. 1933.

THE ECONOMIC ANNALIST

A REVIEW OF AGRICULTURAL BUSINESS PREPARED QUARTERLY BY THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA

Vol. IV, No. 3. September, 1934

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index number of wholesale prices in Canada was fractionally lower in July as compared with June moving downward from 72 1 to 72 0 Vegetable products moved up from 67 4 in June to 68 5 in July. Non-metallic minerals advanced from 85 6 to 86 1 while other sub indexes were lower, the index of animals and their products falling from 66 6 to 65 6 The general index was however 1 5 points above that for July, 1933. While data for the latest month are not available, wholesale prices in United States have been tending upward The index for July, 1933 (Bureau of Labor Statistics) was 68 9 whereas in June, 1934, it was 74 6, the highest point reached in that period. In the United Kingdom the Board of Trade index for June, 1933, was 101 7 as compared with 103 6 in July of this year. There has been a slight tendency for this index to recede. The June index was however well above that for May. In France, wholesale prices have been falling steadily since last December. The index in June of this year was 363 as compared with 396 in the same month in 1933. During the same period wholesale prices in Germany have tended to rise. In Italy they have been moving downward slowly. Monetary policies would of course have to be taken into consideration. These indexes are given however to indicate the course of prices within the respective countries. The general tendency recently has been toward lower levels.

Retail Prices —The Bureau of Statistics index number of retail prices, rents and costs of services rose from 78 2 in May to 78 4 in June, due apparently to advances in the prices of food, in which group the index rose from 67 6 to 68 4. Considering retail prices in several of the more important countries, it is interesting to note that in 1933 the Bureau of Labor Statistics index of prices of foods in the United States was 71.7 in July, 1933, whereas in July, 1934, it was 75 2. The tendency has definitely been upward. Indexes for corresponding dates in the United Kingdom were 118 and 122 In France in July, 1933, the wholesale index was 79 8, whereas in June, 1934, it was 77 5. The tendency has been downward since the first of the year. In Germany, the index of food prices has followed a slightly irregular course rising until December, 1933, and falling to 113 3 in May, 1934. There was however a sharp advance to 115 5 in June.

Physical Volume Business.—Indexes of production for the month of July have been added since this was written, however, taking the trend in the last 12 months into consideration, it will be observed that there has been a substantial increase in business activity. The index for June, 1934, was 95 8 against 82 2 in June, 1933. Similiarly industrial production was 95 2 as compared with 79 8 Mineral production has with the exception of July, 1933, been well above the monthly average for 1926. Manufacturing has been at a higher level as well but perhaps not quite as active as

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64 0	62.6	56.4	77 0	65 4				
1914	65.5	69 2	64.9	79.0	66 0				
1915	70 4	77.7	76.9	79 2	67.3				
1916	84 3	89.7	88.4	92 3	72 5				
1917	114 3	130 0	134 3	119 6	85 6				
1918	127.4	132.9	132.0	134 7	97 4				
1919	134 0	145.5	142 4	152 5	107.2	71.3	65 5	48.1	47.1
1920	155 9	161 6	166 5	149.9	124.2	75.0	69.9	52 6	94.2
1921	110 0	102 8	100.3	108 5	109.2	66.5	60 4	65 2	86.4
1922	97 3	86 7	81.3	99 1	100.0	79 1	76.9	82.6	82.8
1923	98 0	79 8	73.3	95 1	100 0	85 5	83 8	91 4	87 6
1924	99.4	87 0	82 6	97 2	98 0	84.6	82 4	102 5	114.9
1925	102 6	100 4	98 1	105 7	99.3	90 9	89.7	97 2	108.6
1926	100 0	100 0	100 0	100.0	100 0	100 0	100.0	100 9	100.0
1927	97 7	102 1	99 9	105 7	98 4	106 1	105 6	103 6	110 0
1928	96.4	100 7	92.6	114 3	98 9	117 3	117.8	146 7	112 8
1929	95.6	100 8	93 8	112 5	99 9	125.5	127.4	101 1	109.6
1930	86.6	82.3	70 0	102 9	99 2	109 5	108 0	103.0	128 4
1931	72.2	56 3	43.6	77 6	89 6	93 5	90 4	99 0	125.7
1932	66.7	48 4	41 1	60 7	81 4	78 7	74 0	114 3	120.1
1933	67 1	51 0	45 8	59 6	77 7	79.7	76 8	105 1	115 4
1933									
Jan.	63 9	43 6	35 1	57 9	79 1	68 1	62 2	56 1	112 0
Feb.	63.6	43 0	36 0	54 7	78 4	67.0	60 0	76 5	127 6
Mar.	64.4	44 7	38 0	56 0	77.8	68 4	62 5	129 0	135 8
April	65 4	46 8	41.1	56 4	78 0	69 8	65 1	104 1	112 7
May	66 9	51.2	46 9	58 4	77.0	76 4	72 7	95 4	110 4
June	67 6	52 6	49 4	57 9	77 0	82 2	79 8	221 9	119.9
July	70.5	60.1	60 8	59 0	77 2	84.1	82 6	221 9	119.9
Aug.	69 4	57 0	54 9	60 5	78.6	89 8	89 5	197 2	114.2
Sept.	68.9	54 7	49 5	63 4	78 8	90 8	90 2	101 1	115 7
Oct.	67 9	51 4	44.6	62.8	77 9	88 2	87 4	70 5	112.7
Nov.	68 7	53 8	46.7	65 8	78 1	85 5	83 9	41 8	111 1
Dec.	69.0	53.3	45 3	66.6	78 4	86.2	85 1	30 7	107.6
1934									
Jan.	70.6	55.3	47.9	67.8	78 2	86 8	84 5	48 2	108 1
Feb.	72.1	58.0	49 3	72 5	78.7	86 4	84.0	67.1	98 6
Mar.	72 0	56.5	49 5	68 3	79 9	93.1	92 0	63 8	97.0
Apr.	71.1	55 4	48 7	66 6	79.4	92 6	91.4	56 9	94 5
May	71.1	56 9	51 1	66 5	78.5	99.6	99.4	130 6	102 6
June	72.1	59 3	55.5	65 6	78.2	95 8	95 2	97 2	101 2
July	72.0	60 0	57 8	63 7	78 4	95 7	95 6	148 8	

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1931, p. 15.
2. Wholesale prices of Canadian products of farm origin only See Prices and Price Indexes 1913-1931, p. 33, and Monthly Mimeographs 1933 and 1934.
3. Wholesale prices of grains, fruits and vegetables.
4. Wholesale prices of Animals and Animal Products.
5. Including foods, rents, fuel, clothing and sundries. See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.
Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeographs 1933-1934.
6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

mineral output since the index was above the base period only in May of this year. It is interesting to note that tobacco releases have been consistently high during the past twelve months. Production of boots and shoes, output of news print, textiles, electric power production and imports of petroleum have been at high levels.

The index of iron and steel however has been relatively low although there has been rather distinct improvement since the beginning of the year. An important feature has been a fairly consistent improvement in car loadings. The Bureau of Statistics index of construction continues to reflect comparative inactivity in the industries affected, but contracts awarded in July were above those awarded in June. The cost of construction has receded very little during the past twelve months. These facts have already been drawn to the attention of readers of the Annalist.

The index of agricultural marketings has been comparatively low. A smaller movement of wheat and coarse grains is probably largely responsible for this fact. Relatively, marketings of live stock have been at higher levels than those of grain. The probability is that cattle marketings will be comparatively high this fall because of the shortage of feed in sections of the country. Cold storage stocks, which were low earlier in the year, have risen in the past few months.

The Bureau of Statistics reported that on August 1, stocks of creamery butter in cold storage warehouses and creameries were 21.3 per cent above those on August 1, 1933, and supplies of dairy butter were 21 per cent higher. Cheese in storage on the other hand was 3.1 per cent below that of a year ago. Cold storage eggs were 3.2 per cent under the figure for August 1, 1933, while fresh eggs were 30.5 per cent lower. Frozen eggs on the other hand had increased 24.2 per cent. Supplies of pork were 30.5 per cent above those on the same date last year. Beef in storage was 13.5 per cent higher while lard was 48.2 per cent below last year's figure. Veal in store was 28.4 per cent above that on hand a year ago while mutton and lamb was 10.6 per cent less. Supplies of poultry were 27.7 per cent higher.

Agricultural Products.—The index number of wholesale prices of Canadian farm products rose fractionally from 59.3 in June to 60.0 in July. The index of field products advanced from 55.5 to 57.8. Improvement in the prices of grains was largely responsible for this advance. The index of prices of live stock on the other hand fell from 65.6 to 63.7, largely due to comparatively heavy shipments and supplies of unfinished stock.

Crop Conditions.—Recent rains have aided crops in the Maritime Provinces. The Nova Scotia apple crop will be less than that of 1933. Crop conditions in Quebec are reported as generally satisfactory except in the western portion of the province in which drought has been pronounced. Harvest in Ontario is well advanced. Rains have fallen in the Prairie Provinces and have aided crops in the northern districts but the southern sections of Alberta, Saskatchewan, and Manitoba continue to suffer from lack of moisture. Harvesting operations in these provinces began toward the end of July and early in August in some sections, or about two weeks earlier than normal.

In general there has been substantial progress in recovery during the past twelve months. Wholesale prices have risen. Retail prices have advanced but not abnormally; sharp increases in the near future are indicated in certain lines of foods. In this connection, it should be borne in mind that while employment has been more general than it was a year ago, consumers' incomes have not materially advanced. Notwithstanding this, physical volume of business is much larger than a year ago. The index of Retail sales is above that of last year. There has, of course, been some advance in prices which would affect this index. Unsettled political conditions in Europe continue to retard the development of international trade but in spite of this there has been a marked improvement in Canadian exports during recent months.

The Dairy Commission of the Province of Quebec has issued an Ordinance giving effect to the Convention agreed to between milk dealers in Montreal and suppliers of milk in that market fixing the price of milk at $1.45 net F.O.B. Montreal per 100 pounds, milk testing 3.5% butter-fat. A similar Ordinance has been issued fixing the price of milk in Quebec City at $1.35 F.O.B. Quebec per 100 pounds net, milk testing 3.5% of butter-fat. These Ordinances also prohibit price cutting by retail dealers.

AN ECONOMIC ANALYSIS OF CREAMERY OPERATIONS IN NEW BRUNSWICK

C. V. Parker[1] and J. F. Booth[2]

The purpose of this article is to present a synopsis of the results obtained in a study of the business operations of eleven New Brunswick creameries.[3] The data contained in this article were collected in 1933 and apply to the 1932 operations of the creameries.

The production of creamery butter in New Brunswick has increased materially in recent years while the output of cheese has declined. Relatively better prices for butter and increased production of live stock requiring the use of skim milk are responsible in the main for the diversion of milk from cheese factories to creameries. The output of creamery butter in 1932 reached 2,759,519 pounds compared with 1,416,355 pounds in 1926. The production of dairy butter in 1932 was 7,456,000 pounds which, when added to creamery output, made a total of 10,215,519. Domestic consumption of butter, however, is still in excess of supply; there is therefore an opportunity for expansion of the dairy industry. The extent of the expansion will depend largely upon the degree to which dairy farmers increase their home-grown feeds or can buy mill feeds at a sufficiently low price to ensure satisfactory profits on sales of butterfat

From the creamery operator's point of view the chief difficulty in factory operation is in obtaining sufficient quantities of cream for economical operation. There are at present 21 creameries doing business in the province and many of these creameries have a comparatively small output. This difficulty arises from the fact that the agricultural areas are scattered, small and sparsely settled. Patrons in many instances live a considerable distance from the creameries, and in the majority of cases the patron's business is relatively small.

The Provincial Government for the past few years has been aiding creamery operators and patrons alike by contributing to the expenses of cream transportation. This has had the effect of placing on an equal footing all farmers who are within reach of an established creamery. The additional cream received from outlying districts helps to reduce the per unit cost of operations and, without the subsidy from the Government, many of the smaller plants would be forced to cease making butter.

The present study was undertaken for the purpose of obtaining information on the costs of operation in relation to volume of butter production and costs of transporting cream Data on other factors such as financial and operating statements, prices received and so forth were also obtained and taken into account.

The eleven creameries studied made 1,997,516 pounds of butter in the 1932 operating season. Butter output per creamery ranged from 13,448 pounds to 903,600 while the average make was 181,592 pounds. The number of patrons averaged 392 per creamery and varied from 50 to 1,260.

Cost of Manufacture.—The following cost figures do not include the charges for transporting cream to the factory or freight on butter from the factory. Items making up total cost were taken from factory statements with the exception of interest and depreciation charges. Interest was charged on the present value of buildings and equipment at the rate of 5%. On buildings a 2% rate of depreciation was charged for brick and 5% for frame structures. Depreciation of equipment was calculated on the year's future use basis; present values and year's future use were obtained for each of the important items, and by dividing the number of years into the present value, a depreciation figure for the year in which the study was made was obtained.

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[3] In conducting the study the New Brunswick Department of Agriculture co-operated with the Dairy and Economics Branches of the Dominion Department of Agriculture.

TABLE 1.—COST OF MANUFACTURING A POUND OF BUTTER IN 11 NEW BRUNSWICK CREAMERIES, 1932

Creamery	Pounds butter made	Manufacturing expense	Cost per pound butter
		$	cts.
A	49,602	2,877 49	5 80
B	114,275	5,607 41	4 91
C	124,975	5,522 58	4 42
D	224,405	22,311 95	9 94
E	320,062	16,012 30	5.00
F	29,296	3,406 54	11.63
G	62,208	2,369 26	3 81
H	13,448	1,340 23	9 97
I	95,576	2,927 17	3 03
J	903,600	25,891 63	2 86
K	59,069	2,231 15	3 78
Total or average	1,997,516	90,497.71	4 53

The cost of manufacturing a pound of butter for each of the creameries is presented in Table 1. The average cost per pound of butter was found to be 4.53 cents. This figure varied from 2 86 cents to 11.63 cents between individual creameries. While the largest creamery had the lowest unit cost and the two smallest plants had the highest costs the number of factories included in the study was not sufficient to overcome the effect of unusually efficient or inefficient creameries; therefore it was difficult to establish a relationship between volume and costs such as is ordinarily found in cases of this kind and as would undoubtedly be found in this instance if data had been available from a much larger number of factories.

In Table 2, the items of cost are segregated under the headings of Labour, Materials and Miscellaneous, and Overhead. Here we find that labour costs amount to 0.85 cent per pound in factory "J," which had the largest output, while for "H," the smallest plant, the cost is 5 30 cents per pound of butter. Labour charges for factory "D" seem to be considerably out of line with those of other large creameries.

Materials and miscellaneous items comprise approximately 33% of the total charges Under this heading are included manufacturing and office supplies, fuel, ice, light and power, repairs and other items. The amount spent per creamery ranged from $265 to $12,474 for items in this category. On the average the cost of these items per pound of butter was 1 64 cents. Except for creameries "D" and "F" the charges per creamery for these items did not vary greatly from the average. No great difference should occur because the quantity and price of materials used per unit of product manufactured is approximately the same regardless of output.

The items included under overhead were taxes, insurance, interest and depreciation. These formed slightly over 27% of the total manufacturing costs. The average cost of these items per pound of butter was 1.24 cents. This figure varied from 0.54 cent to 3.56 cents for individual creameries, and tended to decrease as production increased.

Cream Transportation Costs.—Approximately two-thirds of the patrons associated with the eleven creameries had their cream hauled to the creamery by the truck-route method. There were 50 routes in operation in 1932. The number of miles travelled by trucks per route was high, averaging 100 miles per return trip and ranging from 15 to 252 miles for individual routes. The cost of operating a route for the season ranged from $21 to $2,037 and averaged $543 per route. The cost per pound butterfat varied from 0.79 cent to 4.78 cents and averaged 2.46 cents on all routes. Distance travelled per route and pounds of butterfat hauled per trip were the main factors influencing the cost of getting the cream to the factory.

TABLE 2.—LABOUR, OPERATING AND OVERHEAD COSTS IN 11 NEW BRUNSWICK CREAMERIES, 1932

Creamery	Pounds butter made	Labour	Materials and miscellaneous	Overhead	Total making costs
		Cents per pound butter			
A	49,602	2 50	1 55	1 76	5 80
B	114,275	2 24	1 48	1.18	4 91
C	124,975	0 90	1 86	1 65	4 42
D	224,405	4 00	2 93	3 01	9 94
E	320,062	2 03	1 56	1 41	5.00
F	29,296	4 49	3 58	3 56	11 63
G	62,208	1 12	1 28	1 41	3 81
H	13,448	5 30	1 97	2 69	9 97
I	95,576	1 34	1 15	0 54	3 03
J	903,600	0 85	1 38	0 64	2 86
K	59,069	1.61	1 24	0 93	3 78
Total or average	1,997,516	1.65	1 64	1 24	4 53

One problem which has a tendency to increase cream transport costs is the overlapping of cream routes. In many places the trucks from two creameries cover almost the same territory while at several places trucks run on the same road as a result of competition for business. It is evident, however, that the patron is paying for this duplication of services and it would be greatly to his advantage if through organization some means could be devised to map out routes in a more efficient manner.

Prices Received.—The average price received for butter by the eleven creameries was 20 2 cents per pound in 1932. On a butterfat basis this figure was 24.4 cents. On the other hand patrons were paid 18 9 cents per pound for butterfat so that creamery men were working on a margin of 5 5 cents. Manufacturing expenses, transport costs on cream routes and freight on butter amounted to slightly over 7 cents per pound butterfat; therefore, the creameries as a whole were operating at a loss in so far as the manufacture of butter was concerned. Interest and depreciation charges were included as an expense.

Business Analysis.—An analysis of the balance sheets and operating statement of the 11 companies takes into account the total business conducted by these firms. Many of the factories make ice cream and some sell milk and cream.

The analysis of the balance sheets for the eleven companies indicated that the majority were in a fairly sound financial condition. While some creameries were carrying a greater amount of current liabilities than could be met by current assets, the current ratio for the eleven concerns as a whole was 1 17 to 1, indicating that the majority were favourably situated in this respect. A less favourable condition is indicated by the proportion of net worth to debt, which was 0.63 to 1 for all companies. This was due wholly to the unsound position of three of the companies. Only two companies carried a reserve for contingencies, but eight of the eleven had a surplus of assets over liabilities.

The analysis of the operating statement, however, indicated that the majority of companies operated at a loss in 1932. Seven of the eleven had a debit balance for net operating income. Six of the companies paid dividends but it is suggested that some of these did so at the expense of drawing on funds which should have been carried into reserve for depreciation purposes. In constructing the operating statements, depreciation charges were adjusted upwards in some cases where sufficient amounts were not being charged to the business. This explains why some companies paid dividends when they apparently had deficits.

EFFORTS TO CONTROL MARKETING BY GOVERNMENT BOARDS OR ORGANIZATIONS ACTING WITH GOVERNMENT SUPPORT

PART III [1]

J. COKE [2]

New Zealand has exercised control of the marketing of farm products for more than a decade. The Meat Export Control Act was passed in 1921 and was followed by the Dairy Produce Control Act in 1923, the Fruit and Honey Control Acts of 1924, and the Kauri Gum Export Control Act of 1925. The Wheat Purchase Board was authorized by Order in Council in 1933. There is a certain similarity in the functions of these boards although the wheat plan includes both domestic and export sales.

The Dairy Produce Control Board consists of 12 members, 9 of which represent dairy farmers, 2 represent the Government, and 1 represents manufacturers of dairy produce. Its finances are provided by a levy of 1/8d. per pound on all butter exported and 1/16d. per pound on all cheese exported. This board has power to exercise either limited or absolute control over marketing of dairy produce. For the greater part of the time, however, it has exercised limited control, that is, it has confined itself to licensing exporters; controlling and improving quality; arranging shipping, insurance, and storage contracts, auditing accounts; supplying market information; and advertising dairy produce under a national brand.

In 1926 intention to exercise absolute control was declared. The board then undertook to regulate distribution and to fix prices to the trade in Great Britain. This aroused opposition both in overseas trade and at home. Large stocks were accumulated in storage which had to be liquidated eventually at unsatisfactory prices. This policy was abandoned in 1927. There is still some support for such a policy in New Zealand because some felt that, had the board held out somewhat longer, better results would have accrued. The desirability of such a policy and other matters related to the overseas market for dairy products are now under investigation by a Royal Commission. A measure of co-operation has been effected with the Australian Dairy Produce Control Board

The Fruit Export Control Board operates on a slightly different basis. A province may vote in favour of having its fruit marketed under control and if 70 per cent of those producing a stated minimum quantity for export are in favour, the fruit shall come under the Control Act. After a period of three years a vote may be taken and should a similar percentage be opposed, the products of the area will not be subject to control. Octago refused to export under the control regulations but in 1933 agreed to do so. The policy of the Board now is to sell through one wholesale firm in Great Britain.

The British Marketing Acts.

An entirely different set-up for marketing is found in the type of co-operation which was provided for under the British Marketing Acts of 1931 and 1933. It should be said that this form of organization was, insofar as I am aware, developed in Queensland, Australia, and took its first form in Wheat Pool Act of 1920 which, in turn, was followed by the Primary Products Act of 1922. The essential feature is that where the majority of producers of a commodity desire to sell the product collectively the minority may be compelled by law to join in such sales policy.

The British Agricultural Marketing Act of 1931 provides for the submission of schemes for the regulation of the marketing of agricultural products to the Minister of Agriculture who will then publish notice of the receipt of the scheme and a period

[1] See The Economic Annalist, Vol III, Nos. 7, 8, 9, pp. 76-78, and Nos. 10, 11 12, pp. 92-95.
[2] Assistant Commissioner, Economics Branch, Department of Agriculture, Ottawa.

of six weeks will be set aside in which all objections must be filed with the Minister. If, on enquiry, the Minister is satisfied that the scheme will be advantageous to the producers of the commodity he may then submit it to parliament for approval. The Minister has power to modify the proposals but these modifications must be acceptable to the proponents of the scheme.

Each scheme is to be administered by a board. Every scheme requires a poll of registered producers affected. Not less than two-thirds of the producers, both in numbers and in volume of production, must vote in favor before the scheme can be adopted. A board constituted under the Act is given wide powers to engage in buying or selling, grading, packing, adapting for sale, and advertising farm products. Consumers committees may be set up to judge of the effects of any scheme on consumers. Two funds are established under the Act—a "Scotch fund" of £125,000 sterling and an "English fund" of £500,000. These funds may be loaned to any board administering a scheme. Both long-term and short-term loans are provided for. Renewals of loans are placed in the hands of agricultural marketing facilities committees. Renewals will not be granted on loans on which the interest has not been paid in full, in fact all renewals are carefully scrutinized.

The Act further provides for Agricultural Marketing Re-organization committees which shall be responsible for the preparation of schemes and review the operations of existing schemes and make recommendations to the Minister. Schemes for marketing hops, milk, pigs, bacon, and potatoes are already in operation and others for beet sugar, poultry, and fat stock are in various stages of development.

The Agricultural Marketing Act of 1933 provides, among other things, that where a board is administering two or more agricultural marketing schemes, one of which relates to a secondary product and one to a primary agricultural product from which the secondary product is wholly or partly manufactured (for example, pigs and bacon) it may submit schemes for the organization of the secondary industry which, under the Act, shall be known as a development scheme and which shall be administered by a development board. A development scheme for the organization of the secondary industry may require that no one shall produce the secondary product unless exempt or in receipt of a licence from the Board within the areas covered by the scheme. The Board may take over premises for the development of the secondary industry and dispose of them as it sees fit. Provision is made for the hearing of protests against such an action. The development boards are also empowered to make a levy on all marketing boards concerned in a development scheme.

This Act also empowers the Board of Trade to regulate imports and provides for setting up a Market Supplies Committee to review the conditions affecting supplies of agricultural produce in the United Kingdom and to advise the Secretaries of State for Scotland and Northern Ireland and the Ministry of Agriculture and Fisheries in regard to desirable policies.

Another amendment to the Act of 1931 is the provision whereby a board may regulate the amounts of a regulated product which any producer may sell. All producers must supply information deemed necessary for the purposes of the board. The Board of Trade is also empowered to obtain information as to stocks of agricultural products on hand.

This legislation has been criticized but obviously has the support of a large number The Minister of Agriculture, speaking at Newton Abbott on March 10, 1933, said —

"What the Marketing Bill says in a nutshell is this—we must organize the home market and the supplies to that market. If and when, however, the industry undertakes so to organize it must be guaranteed that it shall not be swamped out by an unorganized flood of produce landed on our shores in a succession of bankrupt sales. Furthermore, it says that the producer is not merely interested in growing his product but in what is done with it thereafter and that he and the manufacturer can full well come together to organize the secondary products . . . "[3]

Public Utility Control.

Public Utility Control has, until recently, been limited to such services as gas, electric light, water, communications and transport. Since 1932, however, milk prices in Winnipeg have been established by the Public Utilities Commission. The situation was brought about by the failure of representatives of dairy farmers and distributers to agree on prices and was aggravated by competition from chain stores and farmer distributers. The Board was reluctant to undertake this control and, in fact, at first refused to recognize it as coming within its jurisdiction. It was claimed, however, that the milk supply of Winnipeg was endangered and that the producers of fluid milk had equipped their farms for this especial purpose and had no other market; thus it was claimed that milk should be considered to be a public utility and that an emergency did exist.

As already mentioned chain store competition aggravated the situation. The question of chain store efficiency, policy and service relative to that of the regular distributer might have been a matter for consideration. This, however, was considered to be of less importance than the question of effecting a compromise with respect to prices. The prices of class A milk were established at $1.54 to the producer and retail milk, 10 cents per quart, relief milk off the wagon, 8 cents, milk sold to stores, 7½ cents, and bulk milk, 6½ cents.[4] Prior to the establishment of these prices milk was selling at five to eight cents per quart and the producer was receiving less than $1 per hundred pounds.[5] Those critical of public utility control of milk prices claim that there is too much rigidity in the determination of prices and that the preponderance of consumers' interest may adversely affect prices from the farmers' point of view. Nevertheless this plan has spread to cities in Alberta and Saskatchewan.

Another method of establishing prices of milk is found in the setting up of special control boards for that purpose. Thus, in the State of New York, a Milk Control Board has been established for a period of two years with a view to "fixing the minimum price to be paid by milk dealers to producers and others, the maximum price to be paid by the consumer for milk used in fluid consumption, wheresoever produced." The minimum price to producers will, of course, apply to a locality. The Act also provides for price variation according to grades. Similar legislation has been passed in Pennsylvania and Ohio, and in Quebec and Ontario.

The Agricultural Adjustment Act.

The Agricultural Adjustment Act has been in force in United States since early in May, 1933. It does not embody entirely new plans for it is claimed that it has been developed during post war years and is a result of several efforts "to improve the farm situation by legislative and non-legislative measures . . . ."[6] "Previous acts have failed because of inability to cope with the fundamental difficulties of controlling excessive supplies, removing inefficient marketing methods and improving general purchasing power. The Agricultural Adjustment Act goes directly to two of these basic difficulties—unbalanced production and expensive marketing."[7] The former is to be met through the allotment plan and benefit or rental payments, and the latter, through provision for marketing agreements between farmers and the handlers of their products which must be approved by the Secretary of Agriculture before becoming effective.

This Act declares it to be the policy of Congress "to establish and maintain such balance between production and consumption of agricultural commodities and such marketing conditions therefor as will re-establish prices to farmers at a level that will

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[3] Hon. Walter Elliot, "Agricultural Policy," Journal of the Ministry of Agriculture and Fisheries, Vol. XL, No. 1 (April, 1933), p. 18.

[4] Minutes of Proceedings and Evidence of Select Standing Committee on Agriculture and Colonization of the House of Commons (Canada), 1933 (Ottawa. King's Printer, 1933), p. 637.

[5] H. C. Grant, Some Notes on Public Utility Control of Milk in Manitoba, Canada (published in mimeograph form by the Department of Rural Economics and Sociology, University of Manitoba, Winnipeg), p. 4

[6] Ezekiel, M. and Bean, L. H. The Economic Bases for the Agricultural Adjustment Act, pp. 1 (7), Ibid. pp. 58.

[6] Ezekiel, M. and Bean, L. H. The Economic Bases for the Agricultural Adjustment Act, pp. 1.

[7] Ibid. pp. 58

give agricultural products a purchasing power equivalent to that in the period August, 1909–July, 1914. In the case of tobacco the base period shall be the post war period, August, 1919-July, 1929." It was apparently recognized that such a policy would require some time in which to become effective. The interests of the consumers were protected by stating definitely the level of purchasing power to be attained and providing for readjusting farm production. It is worth noting that Title II of the Act provides for refinancing the Agricultural industry.

For the purposes of this article we need consider only the marketing agreements. These may in a large measure be regarded as the counterpart of the schemes set up under the British Marketing Acts but less comprehensive in scope. They apply to specified areas and products. Many of them set minimum prices to producers and limit wholesale and retail prices. Business is allotted between existing units and trade practices are prescribed as are the records to be kept and reports which shall be forwarded to the Secretary of Agriculture. Licences may be issued to dealers. It is hoped that high cost or inefficient marketing agencies may be eliminated. Thus we read: "Agencies entering into agreements with the Secretary of Agriculture may undertake to retire high cost inefficient services and to encourage the expansion of low cost services in the interest of greater volume of distribution relatively lower costs to consumers and a larger share of the consumers' dollar for the farmer." [8]

Regulation of supplies will mean, so it is claimed, better prices to the farmer. Under conditions of control of total supplies and known demand, "price-fixing is feasible" since important elements which determine prices are brought under control. It is recognized that control is limited to supply and to efficiency in marketing since demand is not to be affected except through diversions for relief purposes and by judicious advertising.

In the agreements submitted soon after the Act came into force there was distinct evidence of rigidity but some degree of flexibility is apparent in more recent submissions. This is particularly true in regard to the clauses relating to prices.

Conclusion.

The legislation referred to in these articles is evidence of the growing importance of the State in controlling business. The demand for such control arises in part out of the chaotic conditions of depression, and also is an expression of the necessity of adapting business to meet the requirements of society. We are still groping about for an effective means of increasing business efficiency. In so doing we must be careful to preserve the good points of business organization as we have known it and to add to it such social control as is necessary to protect the interests of the primary producers and those of marketing agencies which are capable of efficiently rendering the services required by consumers.

Dr. H. Barton, Deputy Minister of Agriculture, Dr. J. F. Booth, Economics Branch, Department of Agriculture, Dr. A. K. Eaton, Department of Finance, C. B. Davidson, Dominion Bureau of Statistics, and A. Gosselin, Economics Branch, Department of Agriculture, have been appointed to the Dominion Marketing Board authorized under the Natural Products Marketing Act, 1934. Dr. Barton will act as Chairman. The offices of the Board will, it is understood, be in the Confederation Building, Ottawa.

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[8] Ibid. pp. 64.

FARM CREDIT LEGISLATION IN CANADA, 1934.

Among the more important legislation passed at the fifth session of the 17th Parliament of Canada which prorogued July 3rd, were two bills dealing with Agricultural Credit. There were, Bill 92, "an Act to facilitate Compromises and Arrangements between Farmers and their Creditors" to be known as The Farmers' Creditors Arrangement Act, 1934, and Bill 93, "an Act to amend the Canadian Farm Loan Act," otherwise cited as "The Canadian Farm Loan Act Amendment Act, 1934."

The Farmers' Creditors Arrangement Act, 1934.

Purpose.—The object of this Act is to provide simple and inexpensive machinery and procedure whereby farmers who are unable to meet their liabilities as they become due may propose to their creditors, without actually going into bankruptcy, a composition, extension of time, or scheme of arrangement of their affairs.

Administration.—The administration of the Act is entrusted to the Minister of Finance, the necessary expenses for administration being payable out of any unappropriated moneys in the Consolidated Revenue Fund The machinery of administration is to consist of one or more official receivers appointed by the Governor in Council in each county or district or for any number of counties or districts of any province to which the Act applies, and a provincial board of review for each province. The provincial boards of review which are to be appointed by the Governor in Council are to consist of a judge of the superior court of the province who shall be chief commissioner, a commissioner to represent the interest of creditors, and one to represent the interests of debtors.

Composition of Liabilities.—The Act provides that any farmer who is unable to meet his liabilities as they become due may make a proposal for a composition, extension of time, or scheme of arrangement either before or after an assignment is made, such proposal to be filed with the official receiver of the district who shall perform the duties of official receiver, custodian and trustee under the Bankruptcy Act

Following the filing of a proposal with the official receiver, the property of the debtor will be considered as being under the authority of the court and no creditor shall have any remedy against the property or person of the debtor except with the permission of the court, provided that a stay of proceedings shall not be effective for more than sixty days after the filing of the proposal with the official receiver. This period of time may be extended by court order. Any proposal which is approved by the debtor and his creditors becomes binding on all parties

In any case where the official receiver reports to the Board of Review that a farmer has made a proposal but that no proposal has been approved by the creditors, the Act provides that the Board shall, on written request of a creditor or the debtor, endeavour to formulate a proposal acceptable to all parties concerned. It is required further that such a proposal should be based on the present and prospective ability of the debtor to perform the obligations prescribed and the productive value of the farm. The Board may decline to formulate a proposal in any case where it does not consider that it can do so in fairness and justice to the debtor or the creditors. If any such proposal is approved by the creditors and the debtor, it shall be filed in the court and shall be binding of all persons concerned. Should the debtor or the creditors decline to approve a proposal so formulated, the Board has the power to confirm such proposal either as originally drawn up or as amended by them in which case the proposal will be approved by the court and will be binding on both creditor and debtor.

Interest on Farm Loans.—In connection with interest on farm loans, the Act provides that if, whenever any rate of interest exceeding 7 per cent per annum is stipulated for in any mortgage on farm real estate, the mortgagor tenders or pays to the mortgagee the amount owing on such mortgage and interest to date, together with three months further interest in lieu of notice, no interest shall, after the three months period aforesaid, be chargeable on the mortgage in question at a rate in

excess of 5 per cent per annum. The purpose of this provision is to release farmers from mortgages on which high rates of interest are being paid in order they may take advantage of credit which under the present conditions might be available at lower cost. While the remainder of the Act does not come into force in any province until so proclaimed by the Governor in Council, the above provision regarding rates of interest on farm loans comes into effect immediately.

The Canadian Farm Loan Act Amendment Act, 1934

Purpose.—The purpose of this Act is to further extend the scope of the Canadian Farm Loan Act so that further credit facilities may be placed at the disposal of the farmer in order to enable him to carry on his business.

Powers.—The Act empowers the Board to pay any taxes levied on lands held by the Board as agent of the Crown. Heretofore, such lands were not subject to taxation.

Further additions to the powers of the Board were made providing that additional security on livestock or implements might be obtained where considered necessary to ensure the safety of a loan. The Board was also authorized, in any case where it was considered advisable, to give an extension of time for payment of arrears on loans, to write off amounts owing on account of principal or interest on any loan, and to make advances to borrowers to cover the cost of seed grain, fodder, fertilizer or harvesting expense. The maximum amount of the aggregate loan obtainable under the amended Act was reduced from $10,000 to $7,500.

Funds.—Amendment was also enacted in regard to the financing of the Farm Loan Board providing that the maximum amount of Farm Loan bonds which might be held by the Minister of Finance at any one time should be increased from $15,000,000 to $40,000,000. In order that Farm Loan bonds bearing a low rate of interest might be sold readily to the public, the Act also authorizes the Governor in Council to guarantee the payment of principal and interest on Farm Loan bonds to the amount of $30,000,000.

Further miscellaneous provisions provide for changes to be made in the wording of Farm Loan bonds and for the prepayment of all or part of a loan subject to certain regulations prescribed by the Board.

Supplementary Advances.—This section makes provision for further advances by the Board beyond the limit fixed for first mortgage loans under the Canadian Farm Loan Act. Such an advance may be made to any borrower for a period of not more than six years on the security of a second mortgage on farm lands and of a charge on live stock and other personal property, provided that the aggregate of all loans made to any one borrower does not exceed two-thirds of the appraised value of the land and buildings or the sum of $7,500. The amount advanced on security of the second mortgage and supplementary security may not exceed one-half of that advanced on the security of the first mortgage.

The purposes for which such loans may be used are listed as follows:—

1. To enable debtor to pay existing liabilities.
2. To purchase live stock and equipment necessary for the proper operation of the farm mortgaged.
3. To erect farm buildings or to make any permanent improvements tending to increase the productive value of the land.
4. For any such other purposes relating to the development and operation of the farm as the Board approves.

It is also provided that interest rates for such loans shall not exceed that charged on first mortgage loans by more than one per cent per annum.

Loans to Mortgagees.—In cases where the farmer mortgagor has made an approved composition or arrangement with his creditors under the Farmers' Creditors Arrangement Act, the Board is authorized to make a loan to the mortgagee up to one-quarter of the amount of the mortgage, on condition that such loan be disbursed to

the farmer's account for such purposes in connection with the operation of the farm mortgaged as may be approved by the Board, and the mortgage assigned to the Board as security for the advance. It is further provided that the mortgagee shall not charge the mortgagor a rate of interest on such advances in excess of that payable on the mortgage assigned as security and in no case shall the rate of interest be more than 1 per cent greater than that charged the mortgagee by the Board. The purpose of such a loan is to enable a farmer who has made a composition with his creditors and who would otherwise be unable to finance current farm operations to obtain the necessary working capital. The inducement to the mortgagee to assist the mortgagor is the advantage accruing to him from the continued operation of the mortgaged property by the mortgagor. While the initial period of such a loan is one year, provision is made for extending the time of repayment for a further period not exceeding one year on application of the mortgagee. In this section of the Act "mortgagee" means any loan, trust or insurance company incorporated under Dominion or Provincial laws and may be extended to include such other corporations or persons or classes of corporations or persons as may be designated by the Governor in Council.

MARKETING CONFERENCE AND CO-OPERATIVE INSTITUTE

Under the chairmanship of the newly appointed Minister of Agriculture for Alberta, Honourable F. S Grisdale, a marketing conference and co-operative institute was held at Olds, Alberta, July 24th to 26th. The first of these conferences was held some years ago and represents an effort on the part of the farmers' organizations, provincial government and university to disseminate the utmost information on marketing questions.

This year special consideration was given to the Natural Products Marketing Act recently passed by the Parliament of Canada. The afternoon and evening of the first day were devoted entirely to this legislation and its possible application to Alberta conditions

Included among the subjects for discussion on the second and third days were co-operative marketing of wheat, livestock, poultry and dairy products Dr. H. W. Wood, veteran co-operator of the province, delivered an address on Co-operative Philosophy. The Consumers' co-operative movement was also given a place on the program.

Between two and three hundred were in attendance at the meetings from various parts of Alberta and British Columbia.

The delegates to the conference were quartered in the dormitories of the school of Agriculture and during the several days made full use of the splendid grounds and facilities provided by the institution.

SASKATCHEWAN CO-OPERATIVE CONFERENCE

The Saskatchewan Co-operative Conference was held at the Legislative Buildings, Regina, June 28th and 29th. Mr. C. W. Deaver acted as Chairman of the Conference and Mr. B. N. Arnason of the Co-operation and Markets Branch, Department of Agriculture, was Secretary.

Subjects discussed included: Some Problems of the Co-operative Movement, The Development of Trade with the British Co-operatives, Co-operation Between Consumers' and Producers' Co-operatives, The Development of Consumers' Co-operation, Merchandising of Fuel Oils, A Co-operative Refinery, Co-operative Education, The Natural Products Marketing Act.

Approximately 100 delegates and visitors registered and it was decided that the Conference should convene annually. The following officers were elected: President, C. W. Deaver, Davidson, Saskatchewan; Vice-Presidents, H. L. Fowler, Wilcox, and Mrs. Pearl Johnston, Regina; Secretary, B. N. Arnason, Co-operation and Markets Branch, Department of Agriculture, Regina.

A special session for Managers was devoted to discussion of their problems.

A mimeographed report has been published by the Secretary.

FARMERS' BUSINESS ORGANIZATIONS IN CANADA[1]

Records and statistics properly tabulated and summarized form a basis for investigation and comparative analysis in economic research. Such basic information with respect to the activities of farmers' business organizations for the whole of Canada has not hitherto been available. In certain provinces a record of co-operative activities is obtained each year but in others, with the exception of a return to the Registrar of Companies, no contact has been maintained. For several years the Labour Department of the Dominion Government, with the assistance of some of the provinces, obtained certain information concerning the movement for the purpose of compiling an annual directory. There has, however, been no co-ordinating agency to deal with the accumulation of economic and statistical data necessary for treatment of the subject on a national basis or for the study of experiences and accomplishments in particular fields of activity.

Since one of the purposes for which the Economics Branch was established was to study the farmers' co-operative movement, it was felt that the first step to take should be the acquisition of all the information possible on the activities of such agencies in Canada. To that end arrangements were made for a survey of existing organizations. Information was sought from all farmer-owned and controlled associations, companies, societies, and clubs actively engaged in business regardless of their methods of operation or form of organization. The information thus obtained has now been summarized. It is expected that such a survey will be undertaken annually or at intervals of a few years and that the information obtained will form the basis of a permanent record of co-operative activities.

Summary.—Information obtained by the Economics Branch in the first of these surveys shows that, of the companies at present active, 159 were established within the period from 1880 to 1915. During the next decade and up to the present time organization in business by farmers has made steady growth in numbers, membership and business transacted. The activities of the larger organizations such as wheat pools, live stock and fruit co-operatives have reached a high stage of development, and have received world wide recognition but the combined strength of organization in business of farmers in Canada has never been revealed. There are hundreds of comparatively small organizations which are working quietly and effectively serving local areas which are being discovered and recognized in this survey.

This report covering the business year of 1931 deals with the activities of 795 farmers' business organizations having 2,706 local branches making a total of 3,501 places of business. The shareholders and members financially interested number 379,687. The total investment of shareholders and members amounts to $38,643,598 exclusive of reserves of $7,732,027. Combined assets total $70,226,288 with plant and equipment valued at $45,607,366.

Sales of farm products for the period under review amounted to $134,611,154. The sales value of purchased goods totalled $10,665,503 and other receipts $27,297, which combined means a total business of $145,303,954. It should be kept in mind that this was a period of low prices with the index of farm prices standing at nearly 50 per cent below the 1926 level.

The farm produce marketed co-operatively in Canada as taken from returns received is given as an estimate. Whole milk handled amounted to 1,994,056 hundredweight, butter 34,357,329 pounds, cheese 19,324,907 pounds, apples 2,356,308 boxes and 675,019 barrels, potatoes 809,951 hundredweight. Live stock handlings totalled 3,496,647 hundredweight, poultry 12,341,822 pounds and 16,424,822 dozen eggs, and grain marketed is estimated at 175,580,591 bushels.

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[1] This short article has been adapted from a bulletin entitled "Farmers' Business Organizations in Canada", now in Press. The co-operation of the Department of Labour, Provincial Registrars of Co-operative Associations and a large number of farmers' business concerns is gratefully acknowledged.

ECONOMIC LITERATURE

AYRES, L. P. The Economics of Recovery, MacMillan Co., New York, pp. 185, 1933.

This book reviews the origins and the progress of the depression in the United States and undertakes to make an analysis of the more important measures of legislation that have been enacted to meet the emergency, to consider their economic implications and the probable degree of effective aid that may be expected from them. In the final chapter an attempt is made to identify the fundamental requirements for recovery.

In his "estimate of the situation" Col. Ayres attributes the greater part of the trouble arising out of the depression to two factors. These are--"The great and irregular decline in price levels that paralyzed business" and "the long-drawn-out series of crises in credit."

He classifies all efforts of governments to aid in initiating business recovery from a depression into two groups—efforts to remove barriers blockading business, and attempts to stimulate business, and manipulation of money and credit through inflation In this connection, he says, "Probably the fundamental principle of wise public policy in dealing with a serious business depression is that the national government should devote its efforts to the removal of those barriers that impede or prevent business recovery." Among these he includes money, the credit system, the railroad industry, taxation and the national budget, and trade relations with foreign nations.

In his discussion of Agricultural Relief, the author is critical of the Agricultural Adjustment Act and deprecates the farmers' need of relief, maintaining that their position has been better than that of industrial workers for some years. In summing up he states, "In the long run the effective remedy is to allow the material rewards of farming to work out their own cure by determining the number of farmers that the country can support . Our experiments in the political planning of Agricultural production and farm prices have so far proved exceedingly costly and almost entirely unsuccessful."

The N.R.A. is denounced by the author as being unsound. Discussing what he terms as the reversal of the sequence of events in a recovery, he says, "In previous periods of business recovery industrial prices and volume of production have moved up ahead of wage increases. This has enabled producers to make profits and so has made it possible for them to secure bank credit with which further to expand output and to increase the volume of employment . . . This time the theory of the new arrangement is that business should advance the increased purchasing power first, and then trust to resulting greater demands and increased output to make good the advances." He goes on to say that the obstacle in the way of the working out of this theory is that after four years of depression thousands of businesses cannot operate even temporarily at the losses resulting from the increased costs imposed by the new codes and still secure bank credit with which to expand operations.

Discussing inflation, Col. Ayres states, "The prospect of inflation and the programs of the inflationists paralyze initiative in the production of long-term goods because they threaten an indefinite expansion instead of the enduring control of the money and credit of the nation."

With regard to foreign trade, he expresses the opinion that, "Under the circumstances it would seem wise for us to accept as one of the conditions of recovery problem a continuing restriction in the volume and value of our export trade." With this in mind he challenges the wisdom of spending vast sums to open up new agricultural areas, to provide appropriations for agricultural experimentation and education and for loans for farmers.

The last chapter of the book is devoted to requisites for recovery. These are as follows: 1. The expansion of private enterprise rather than expenditure of public funds. 2. The re-establishment of sound money. 3. The re-financing of indebtedness.

CURRENT ECONOMIC PUBLICATIONS

Imperial Economic Committee. Cattle and Beef Survey. A Summary of Production and Trade in British Empire and Foreign Countries I.E.C/S 1, His Majesty's Stationery Office, London, England.

Dominion Bureau of Statistics. Seventh Census of Canada, 1931. Population by Areas. Printing Bureau, Ottawa.

Agricultural Economics Research Institute, Oxford. The Agricultural Register 1933-34. Issued by the Agricultural Economics Research Institute, Oxford, England.

Contributions to Canadian Economics, Vol. VII, 1934. University of Toronto Studies, History and Economics. University of Toronto Press, Toronto.

NOTES

The Cattle Industry Bill (emergency provision) was introduced into the British House of Commons on July 18th. This Bill established a fund to be known as the cattle fund out of which payments may be made on steers, heifers or cow heifers certified to conform to standards prescribed in the Act or on carcases of such animals. In the case of live animals payments shall not exceed 5s. per cwt. or in the case of a carcase shall not exceed 9s. 4d. per cwt., these payments may be made from a date to be proclaimed by the Minister until March 31, 1935, after which they shall cease and it is anticipated that a permanent scheme may come into effect at that time. Imported cattle are to be marked. The payment on an imported animal can only be secured when it is known that it has been in the United Kingdom for at least three months.

Dr. T. W. Grindley, Dominion Bureau of Statistics, Dr. Wm. Allen, University of Saskatchewan, and Dr. J. E. Lattimer, Macdonald College, P.Q., attended the International Conference of Agricultural Economists held at Bad Eilsen, Hanover, Germany, August 26th to September 2nd.

Mr. A. E. Richards, Economics Branch, Department of Agriculture, Ottawa, is at present engaged in a study of certain phases of apple marketing in the Annapolis Valley, Nova Scotia. This study is being conducted in co-operation with the Nova Scotia Department of Agriculture.

G. A. Newman, Assistant Trade Commissioner, London, England, writing in the Commercial Intelligence Journal reports that during the past six months (July 25) there has been more tomato puree, tomato sauce, ketchup and tomato soup imported from Canada into the United Kingdom than from any other country.

The Dairy and Economics Branches of the Federal Department of Agriculture are co-operating with the Dairy Branches of the Provincial Departments of Agriculture in Manitoba, Saskatchewan, and Alberta in a study of creamery management problems in the respective provinces.

G. H. Craig, University of Alberta, has undertaken a study of dairy production and marketing problems in areas surrounding Edmonton and Calgary. Field work in connection with production is now well under way The Economics Branch, Department of Agriculture, Ottawa, is co-operating in this work.

Marketings of wheat in the three Prairie Provinces during the crop year up to July 27, 1934, were 226,808,811 bushels as compared with 370,611,784 bushels in the same period in 1932-33.

Exports of live cattle from Canada to Great Britain up to August 9, 1934, were 31,475 head as compared with 30,100 head during the same period in 1933.

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THE SIGNIFICANCE OF DEMAND IN THE DETERMINATION OF THE PRICES OF BEEF AND PORK IN CANADA FROM 1920 TO 1932

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A great deal of confusion of thought has resulted from the drastic decline in prices from 1929 to 1933, during which period the prices of things produced by farmers for sale have fallen considerably more than the prices of the things they need to buy. Apparently consumers are paying about all that they are able to pay for food. Producers maintain that they are not receiving sufficient income to maintain production, some asserting that in many cases middlemen deliberately attempt to force prices down by means of agreements or understandings. It has been stated repeatedly within recent years that the only way to bring back prosperity is to increase substantially the income of the farmer. This idea is behind all the schemes which would restrict production or introduce so-called orderly marketing to raise the price per unit to the producer. The assumption is that the consumer can be forced to pay a higher price for the same quantity, or almost the same quantity of food out of his seriously depleted income. In the final analysis the important consideration to the farmer is not so much price per unit as it is total quantity times price per unit. It is quite conceivable that for some products a higher price per unit with smaller quantity sold might give no greater farm receipts than would come from a larger quantity sold at a lower price; thus the only advantage to be gained from the smaller volume of sales might be lower total costs. Many are questioning whether or not the small net gain would be sufficient recompense for all the costs involved in the control and supervision which would be necessary to restrict the amount sold.

No attempt is made in this paper to take issue with any particular group regarding the above contentious points, but rather to present a few observations on the domestic demand and prices paid for beef and pork since 1920. Special emphasis is given to the demand side, as it appears to be the feature which is the least understood, and possibly for that reason the most neglected in the various discussions about meat prices.

THE RELATION OF URBAN INCOMES TO URBAN EXPENDITURES FOR MEATS

The measure of urban incomes used in this analysis is total wages and salaries paid to those gainfully employed in manufacturing, mining, operating steam railroads, and construction. The method of constructing the

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TABLE 1.—DATA USED IN OBTAINING INDEX NUMBERS OF ESTIMATED TOTAL WAGES AND SALARIES PER CAPITA FOR THE URBAN POPULATION OF CANADA, 1920 TO 1932.

Year	Wages, salaries of manufacturing establishments and mining[1]		Wages and salaries steam railways[2]		Value of construction contracts awarded[3]		Index Nos. of estimated total wages, salaries of urban population 1923-27 = 100	Index Nos. of urban population[4] 1923-27 = 100	Index numbers of wages and salaries per capita of urban population 1923-27 = 100
	Millions of dollars	Index 1923-27 = 100	Millions of dollars	Index 1923-27 = 100	Millions of dollars	Index 1923-27 = 100			
1920	732.1	119.0	302.7	118.0	255.6	76.1	109.3	88.5	123.5
1921	518.8	84.4	258.2	100.7	240.1	71.5	85.8	91.6	93.7
1922	510.4	83.0	243.1	94.8	331.8	98.7	89.5	93.8	95.4
1923	571.5	92.9	264.0	102.9	314.2	93.5	95.6	95.3	100.3
1924	559.9	91.0	250.0	97.5	276.3	82.2	90.8	97.4	93.2
1925	596.0	96.9	247.7	96.6	298.0	88.7	95.0	99.8	95.2
1926	653.9	106.3	253.4	98.8	372.9	111.0	105.4	102.3	103.0
1927	693.9	112.8	267.1	104.2	419.0	124.7	113.2	105.1	107.7
1928	755.2	122.8	287.8	112.2	472.0	140.5	123.9	108.1	114.6
1929	809.0	131.5	290.7	113.4	576.7	171.6	135.6	110.9	122.3
1930	736.1	119.7	268.3	104.6	457.0	136.0	119.4	113.7	105.0
1931	624.5	101.6	229.5	89.5	315.5	93.9	96.8	116.5	83.1
1932	505.9	82.3	181.1	70.6	132.9	39.5	69.7	117.9	59.1

[1] Annual Census of Manufacturing Industries Dom Bureau of Statistics

[2] Annual Reports of Railways Dom Bureau of Statistics.

[3] The Dom Bureau of Statistics Reports.

In combining the index numbers of wages and salaries for manufacturing, steam railways and construction, for the purpose of constructing the total index the following weights were used manufacturing and mining 5.2; steam railways, 2.6, construction, 2.2. According to the 1931 Census these were the proportions in which total salaries and wages were distributed to these three general types of gainful occupations.

As annual data for wages and salaries paid in the construction industry are not available it was assumed that total wages and salaries would vary approximately as the value of construction contracts awarded. This index of total demand is more accurate than one calculated by using indexes of wage rates and employment figures.

[4] The Dominion Census of 1921 reported the total population to be 8,788,000 of which 49.9% were urban The 1931 Census reported a total population of 10,377,000, of which 53.7% were urban. The percentages of urban population for the intervening years were calculated by the straight line method between the two census periods. These percentages were then applied to the estimated total population for each year Because of the return of many urban people to the country the normal annual percentage increase in urban population was not assumed to have taken place and the 1931 percentage of urban population was used in making the estimates for 1932.

index numbers is explained in the footnotes to Table 1, to which reference should now be made (See Table 1).

The method of calculating the relative changes in amounts spent by urban consumers for beef, veal, pork, and mutton is explained in the footnotes accompanying Table 2, to which reference is now required.

Total wages and salaries paid in Canada increased steadily from 1921 to 1929 with the exception of a small reduction in 1924. On a base of 1923-1927 = 100 this index increased from 85.8 to 135.6. On a per capita basis, this increase was from 93.7 to 122.3 (Table 1). This rise in per capita wages and salaries of 30% in 8 years was followed by a drastic drop from an index of 122.3 in 1929 to 59.1 in 1932. Preliminary data for 1933 indicate that total wages and salaries were lower than in 1932. This

TABLE 2.—STATISTICS OF URBAN CONSUMPTION AND URBAN CONSUMERS' EXPENDITURES FOR BEEF, VEAL, PORK, MUTTON AND LAMB AND ALL MEATS. INDEX NUMBERS OF ESTIMATED EXPENDITURES FOR MEAT BY THE URBAN POPULATION OF CANADA. 1920-1932.

Year	Beef		Veal		Pork		Mutton, Lamb		All Meats		
	Consumption Millions of lbs.	Expenditure Millions of dollars	Consumption Millions of lbs.	Expenditure Millions of dollars	Consumption Millions of lbs.	Expenditure Millions of dollars	Consumption Millions of lbs	Expenditure Millions of dollars	Consumption Millions of lbs [1]	Expenditure Millions of dollars[2]	1923 to 1927 =100
1920	263.5	78.0	24.0	6.6	211.9	11.7	24.2	8.6	523.6	204.8	108.2
1921	235.3	56.9	20.0	4.5	207.7	95.3	30.5	8.9	493.5	165.7	87.6
1922	282.3	57.9	30.5	5.7	261.7	101.8	29.9	8.2	604.4	173.6	91.7
1923	288.1	56.5	27.0	4.9	292.8	107.7	34.5	9.5	642.6	178.7	94.4
1924	279.1	53.6	31.3	5.6	321.7	102.3	23.0	6.4	655.1	167.9	88.7
1925	319.5	62.6	36.7	6.7	313.5	113.8	22.7	6.6	692.4	189.6	100.2
1926	321.7	65.9	34.4	6.6	287.9	116.9	21.9	6.5	665.9	196.0	103.4
1927	331.6	72.3	43.2	8.8	337.8	125.3	25.8	7.5	738.4	213.9	113.1
1928	316.0	79.6	40.0	9.0	371.5	133.0	31.0	9.3	758.5	231.0	122.1
1929	332.3	90.4	37.5	9.2	377.4	141.5	30.9	9.5	778.2	250.6	132.5
1930	329.8	87.7	48.1	11.4	330.5	125.3	33.7	10.2	742.2	234.7	124.0
1931	336.3	67.6	43.7	8.0	350.0	99.8	35.7	9.1	765.7	184.4	97.5
1932	307.3	51.9	43.2	6.0	396.1	70.5	36.9	7.8	783.5	136.2	72.0

[1] Data on urban consumption of meats were calculated as follows Total dressed weight of slaughterings was taken from the Annual Reports of the Census of Manufacturing Establishments These data include the slaughterings by all Packing Plants and Abattoirs in Canada, both inspected and uninspected exclusive of small local butchers It was assumed that some of this meat consumed by the agricultural population would be partially offset by direct sales of farm slaughter and sales of small local butchers to urban consumers The above data were adjusted by net imports and exports of dressed meats and changes in year to year cold storage holdings to arrive at net total consumption figures

[2] Estimated expenditures for each kind of meat were calculated by multiplying net annual consumption figures by composite retail prices computed with varying weights for each retail cut. The retail cuts with their respective price weights were as follows: beef, sirloin, (1), Chuck, (2), veal, leg of veal, (1); Pork, breakfast bacon, (4), Fresh pork, (1), Mutton and lamb leg of lamb (1). These were the only annual retail quotations available in a continuous official series. It is not suggested that by this method the exact total retail expenditures for meat can be obtained. At best the annual totals will be approximate only. But the annual percentage changes of total retail expenditures will be very close to the true annual percentage changes.

severe decline in urban income, amounting to 51% in three years, takes into consideration both wage rates and unemployment and gives some indication of the recent drastic decline in domestic demand for food products. In three years the demand for farm products contracted more than it had expanded during the previous 8 years.

The variations in expenditures for meat by urban consumers follow closely variations in total wages and salaries (Figure 1). During the past 13 years expansion and contraction of total wages and salaries apparently have governed to a remarkable degree the amount that consumers have spent on meats. For the 13 year period the coefficient of correlation between total wages and salaries and expenditures for meat was +.98 ± .007. In the case of the expenditures for pork alone the correlation was +.967 ±.019; and for beef alone +.93 ±.039. For veal and mutton the expenditures appeared to lag about a year behind changes in wages and salaries. Comparing the wages of the year previous with current expenditures for veal the correlation was +.779 ±.118; and for mutton +.671 ±.166.

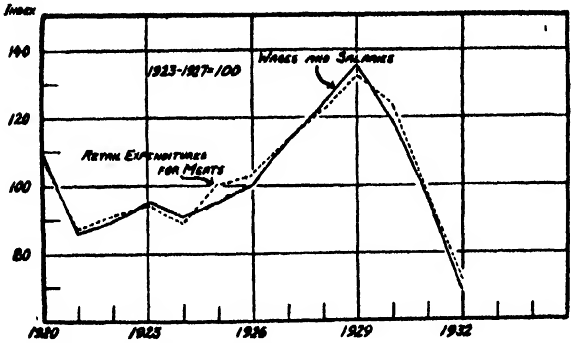

FIGURE 1. Annual changes in index numbers for wages and salaries of the urban population and urban expenditures for meat. Canada, 1920-1932. Total expenditure for all meats tends to fluctuate closely with total wages and salaries.

As wages and salaries decline there is a tendency for a slightly higher percentage of the income to be spent on meats, and as wages and salaries increase there is a tendency for a slightly lower percentage of the total income to be spent on meat. When wages are cut severely food is the last item of expense to be reduced, whereas when wages rise a larger proportion of the income, after food requirements have been met, will be spent on things other than food.

As the incomes of the consumers fluctuate closely with their expenditures for meats, it should not be assumed that a given percentage increase or decrease in income would be accompanied by an equal increase or decrease in total farm income from livestock sold. Because of the many fairly rigid costs between the producer and the ultimate consumer, increases or decreases in consumers' incomes are reflected in relatively greater changes in total farm incomes obtained from sales of food products. The response of total farm incomes from different meats to changes in total wages varies with the elasticity of demand for the individual commodity. This question will be discussed later.

A certain degree of substantiation of the above discussion of the relationship between consumers' expenditure for meats and consumers' incomes is indicated by fairly recent research of Bean (*1*). Using annual data from 1920 to 1932 he showed that for the United States retail values of the consumption of pork, beef, mutton and creamery butter bear strikingly high correlations to indexes of consumers' incomes. Using monthly data L. H. Bean and Mordecai Ezekiel showed that the combined farm cash incomes from meat animals, dairy products and poultry products from 1924 to 1933 were highly correlated with pay rolls (*3*). The conclusions reached by these writers were as follows:—"Returns to farmers for their marketings of farm products depend by and large on the money income of consumers in general. This is particularly true of returns from the production of meat animals, dairy and poultry products, and other commodities, that are sold chiefly in domestic markets. . . . . "

THE EFFECT OF DEMAND, AS REPRESENTED BY WAGES AND SALARIES, ON PRICES PAID FOR BEEF

In order to isolate as far as possible the effect of demand on prices paid for beef it was necessary to explain all or nearly all of the variations in the prices paid for beef during the 13 years 1920 to 1932. The statistical method used was the graphic curvilinear correlation method developed by

Bean (*2*). It was found that practically all the variations in prices[2] paid for beef during these years could be explained by the following six factors; (1) the supply of beef;[3] (2) wages and salaries per capita; (3) exports of cattle;[4] (4) supply of pork; (5) supply of mutton; and (6) time. The uncorrected index of multiple correlation between these six factors and the price of beef was .987, indicating that 97.4% of the variations in price were accounted for. In measuring the approximate influence of the six factors three measures are shown in Table 3; (1) the maximum range in cents per pound for each factor during the 13 years; (2) the total price variation for each factor measured as deviations from the average readings of the respective curves; and (3) these respective price variations expressed as a percentage of the total price variations. From this table it will readily be seen that 54% of the variations in prices of beef could be attributed to wages and salaries; 16% to the supply of beef; 13% to supply of pork; 8% to exports of cattle; 6% to supply of mutton and 3% to time, or an upward trend of demand from 1920 to 1932.

The striking fact is the strong influence of demand which was responsible for three times as much price variation as the supply of beef, and appeared to be considerably more important than the combined influence of the supply of beef, pork, and mutton. However consideration must be given to the fact that the 13 years, from 1920 to 1932, are heavily weighted with three years with wages and employment at very high levels (1920, 1928 and 1929) and three years (1921, 1931 and 1932) of very low wages and considerable unemployment. Because of the rapid changes in wages and employment during these years it is natural to expect that demand would have considerable influence on the prices paid for meats. Had a longer period been studied in which fluctuations in employment and wage rates had been less violent, demand might have had less influence in the determination of prices.

The separate net effect of each factor is shown in the curves in Figure 2. The most important curve and the one with which we are most concerned is that for demand (X_3). When total wages were comparatively low the first increases of wages did not cause a very great increase in demand for beef. After a certain point had been reached however, further increases in total wages and salaries resulted in a rapid rise in demand. When wages and salaries reached a comparatively high level further increases caused very little change in the demand for beef. These phenomena might be explained by the fact that in a time of depression, although wages are low and unemployment is widespread, comparatively few people actually experience acute shortage of food while many suffer from deficiency of clothing and lack of attention to health requirements. Upon the resumption of gainful employment the workers pay early attention to these neglected items. After these wants are satisfied further increases in incomes go partly to a higher level of food consumption. Eventually a

[2] Annual prices paid for beef and pork as used in this study are annual average prices per pound dressed for all meats purchased by all the packing plants in Canada, including both uninspected and inspected plants, excluding small local butchers Gross amounts and value are published annually in the Annual Census of the Meat Packing Industry by the Dominion Bureau of Statistics. The prices paid per pound were calculated by dividing the annual data of total value by the annual data of total weight in pounds. For beef the price is that for total weight of beef and veal combined.

[3] Supply of beef, pork and mutton as used in this study is the total weight of dressed meats purchased by the packing plants as indicated above expressed as percentages of trend to eliminate the upward trend of supply from 1920 to 1932. For beef the supply includes veal purchased.

[4] Exports of cattle were adjusted to include veal calves for which a weight of one-fifth was given.

TABLE 3.—FACTORS AFFECTING THE PRICE OF BEEF AND VEAL

Year Time X_7	Supply of beef X_2	Demand X_3	Export of cattle* X_4	Supply of pork X_5	Supply of mutton X_6	Readings from respective curves (cents per pound) X_2	X_3	X_4	X_5	X_6	X_7	Estimated price	Actual price beef X_1	Difference
1920	+ 1 0	123.5	260.0	− 9 0	− 0 6	11 2	+4.4	+0 6	+0 8	0 0	−0 3	16.7	16.8	+0.1
1921	−14 2	93 7	189.0	−20 4	+13.2	13.1	−2 6	0 0	+2 0	−0.2	−0 2	12.1	12.1	0.0
1922	+ 0 2	95.4	220 0	− 7 0	+15.3	11.2	−2 4	+0 3	+0 5	−0.2	+0 2	9 2	9.0	−0 2
1923	− 3 6	100 3	167.0	+ 1 4	+18 9	11 7	−1.8	−0.5	0 0	−0.2	−0 1	9.1	9.1	0.0
1924	− 2.7	93 2	192 0	+24 5	−15.5	11 6	−2.6	0.0	−0 4	+0 4	−0.1	8 9	8.7	−0.2
1925	+ 6.3	95.2	219 0	+18 7	−21.9	10.5	−2 5	+0 3	−0 2	+1.0	0 0	9.1	9.3	+0.2
1926	+ 7.9	103 0	192 0	+ 6 0	−23 3	10 3	−1.0	0 0	0 0	+1.0	0 0	10.3	10.1	−0.2
1927	+15.3	107.7	236 0	+ 8 0	− 9 9	9 6	+1 5	+0 4	0 0	+0 1	0 0	11 6	11.6	0.0
1928	+ 6.1	114 6	188 0	+ 4 9	− 1 1	10.5	+4 1	0 0	0 0	0 0	+0.1	14 7	14.9	+0.2
1929	+ 4 6	122.3	185 0	− 1 2	− 1 1	10.7	+4 4	0 0	0 0	+0 0	+0 1	15.2	15.0	−0.2
1930	− 4.7	105.0	36 0	−20.2	+ 4 0	11 9	+0.1	−0 8	+2 0	0.0	+0 2	13.4	13 5	+0.1
1931	− 3.2	83.1	44.0	− 9 7	+15 0	11 7	−3 3	−0 8	+1 0	−0.1	+0 2	8 7	8.9	+0.2
1932	−11.7	59.1	29.0	+ 4 3	+ 6 3	12 8	−4 9	−0 8	0 0	−0.1	+0 3	7.3	7.2	−0.1
Standard deviation						......	......	......	......	......	......	2 84	2.87	
(1) Maximum range						3 5	9 3	1 4	2.4	1 2	0 6	(cents per pound)		
(2) Total price variations attributed to each factor						10 1	34 2	4 9	8 1	3 8	1 8			
(3) Percentage of price variations attributed to each factor						16 0	54 0	8 0	13 0	6 0	3 0			

*Thousands of cattle.

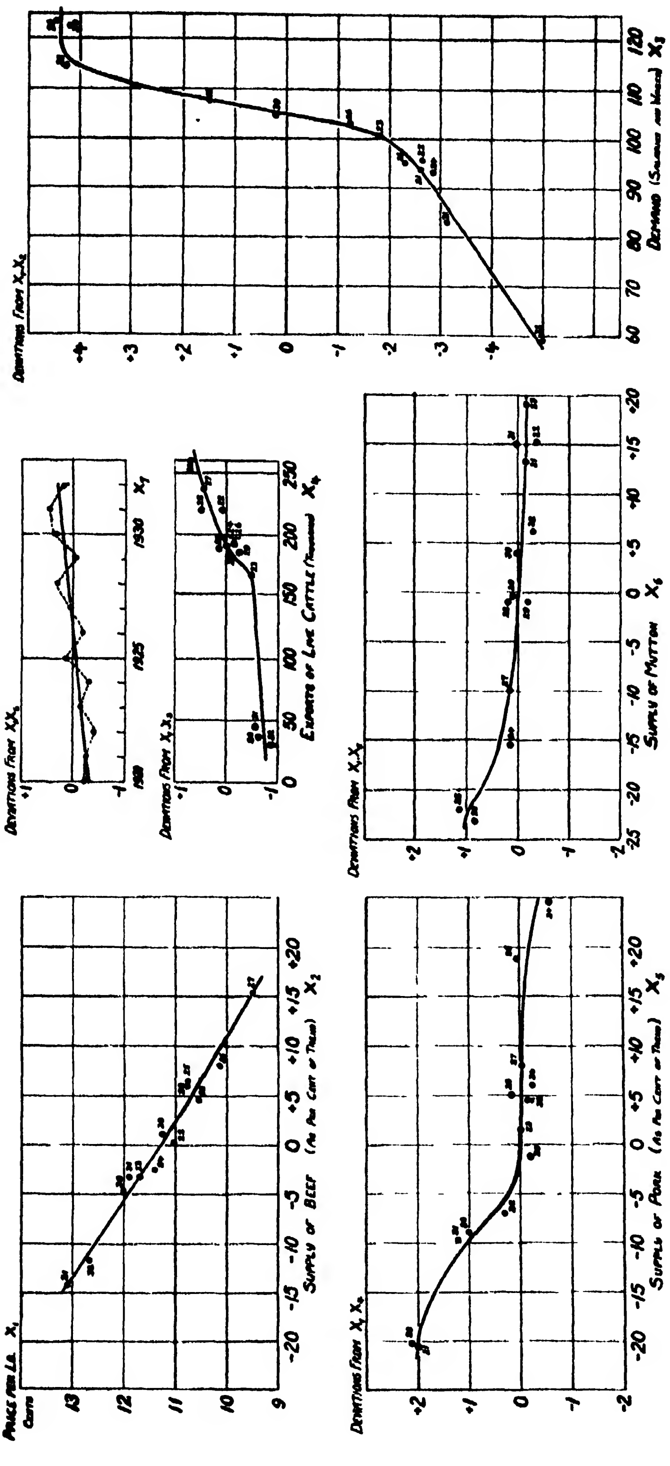

FIGURE 2. Factors affecting the price paid by packers for beef. Canada, 1920 to 1932.

point is reached when further increases in salaries go into luxury and semi-luxury goods rather than food. In support of this explanation the wage curve (X_3) indicates that the increase in demand for beef rose slowly at first, and became stronger as wages and salaries picked up, tapering off as payrolls reached a high level.

Two years, 1921 and 1930, were largely responsible for the comparatively strong influence of the supply of pork on the price of beef (Figure 2). It is just possible that the short period on which this study is based might tend to overemphasize the importance of this factor. The only years that appeared to influence beef prices to any appreciable extent were years in which there was a very short supply of pork, such as 1921 and 1930. Years of large supply of pork appeared to have little influence on the price of beef.

The small influence of mutton supply on beef prices was limited to two years of very low supply, 1925 and 1926.

Exports of cattle have been fairly important in determining the price paid for beef, the greater the exports the higher being the price. Since the war, with the exception of the years 1930, 1931 and 1932, Canada has exported annually at least 150,000 head of cattle. Apparently Canada produces annually a surplus of cattle over its domestic requirements and requires an outlet for at least 150,000 head to maintain domestic prices at a reasonable level. In this statistical study it must be clearly understood that these curves are net effect curves which are obtained by simultaneously holding the other factors constant at their average values. The curve showing the net effect of exports of cattle (X_4) would indicate that, holding all the other factors constant at their average values of the 13 years, an increase in exports of live cattle from 50,000 head to 250,000 head would have resulted in an increase in prices paid for beef of 1.25 cents per pound.[6]

The residual variations in price unaccounted for by the first five factors when plotted against time (X_7) (i.e. 1920 to 1932) had a definite upward trend. This apparently indicates that apart from the influence of the other factors discussed there has been a tendency during the 13 years for an upward secular trend in demand. That is to say, there has been a gradual tendency for consumers to pay a slightly higher price for the same quantity of beef or to pay the same price for a slightly greater quantity of beef. This is distinctly apart from any increase in wages or employment. In the 13 years this increase amounts to 0 6 cents per pound dressed or about 0.3 cents live weight. At this rate of increase it would take 40 years to show an increase of 1 cent per pound live weight due to a gradual change in demand. There are a number of possible reasons for this secular trend in demand but they cannot be enlarged upon in this article.

Murray in a study of factors affecting the price of fat cattle in England from 1893 to 1925 (*5a*) found that the purchasing power of wages accounted for 70% of the variations in the purchasing power of fat cattle, and supply

[6] At this point it is advisable to indicate one of the limitations of multiple correlation analysis. The assumption of multiple correlation is that in measuring the net effect of any one independent variable the other variables are held constant at their average value But when the effect on the dependent variable (price in this case) due to changing one independent variable is dependent upon the magnitude of another independent variable, multiple correlation will not state the true relationship. In the case above it is quite possible that the net effect of export of cattle on the domestic price depends upon the level of demand at the time. In other words, an increase in exports of cattle from 50 thousand to 250 thousand head with a very low level of domestic demand might raise domestic prices more than when domestic demand is at a high level. This would be an example of joint correlation. For further comments on this matter the reader is referred to Cornell University, memoir, 141: "Multiple Correlation Analysis as Applied to Farm Management Research." by Stanley W. Warren, May 1932.

accounted for 14%. The wage index used was based on wage rates and so the total annual wage payments were not taken into consideration.

THE EFFECT OF DEMAND ON PRICES PAID FOR PORK

Four factors were found to explain practically all the variations in dressed hog prices from 1920 to 1932; supply of hogs (X_2); demand (X_3); exports of bacon, ham and fresh pork (X_4); and exports of lard (X_5). The unadjusted index of multiple correlation using these four factors was .998 which indicates that for the 13 years practically all the price variations were accounted for. Demand, and exports of bacon, hams and pork were of equal importance, 30% of the price variations being attributed to each of these two factors (Table 4). Of the other factors, 28% of the variations in price were attributed to supply and 12% to export of lard.

The residual unexplained price variations after allowing for the effect of the first three factors, X_2, X_3, X_4, were plotted against various independent variables in an effort to explain them. They did not show any trend when plotted against time. This would indicate that unlike beef there was no gradual upward secular trend in the demand for pork.[6] The residuals were also plotted against the supply of beef as used in the beef price analysis. There appeared to be a positive correlation which on the surface might be considered to indicate that the price of pork increased with an increase in supply of beef, which of course is illogical, making further investigation necessary. During the period 1920 to 1932 there was a positive gross correlation between supply of beef and price of beef which was itself correlated with the unexplained differences in pork prices. That is to say in most years the price of beef increased at the same time that the supply purchased by all the packing plants of Canada was increasing, and also decreased when the supply of beef fell off. This positive correlation however was due to the strong influence of demand during these few years, rising from 1921 to 1929 and falling in 1920, 1931 and 1932. As beef prices were in themselves correlated with demand (X_3), being largely determined by demand during the period studied, it was decided not to include two independent variables (demand and price of beef) that are in themselves so highly correlated. Because the exports of lard were found to explain fairly well the residual variations they were included as variable (X_5). It is not suggested that exports of lard actually have as much influence on pork prices as indicated by Table 4, as apparently a considerable portion of that influence is caused by the price of beef, the net effect of which it was not possible to isolate by this analysis. Much greater reliance can be placed on the importance of supply, demand, and exports of pork than on exports of lard in the determination of pork prices.

The net curves for each factor are shown in Figure 3. The supply curve for pork has a somewhat steeper slope than that for beef. The curve for wages and salaries (X_3) is very similar in shape to the one for this factor in the beef analysis. The curve of net effect for exports (X_4) is very significant, indicating a strong and favourable influence on domestic prices, especially after the exports reached about 100 million pounds per year.

[6] In this connection it is of interest that the purchasing power of hogs (i e price of hogs divided by the wholesale index) from 1920 to 1932 does not show any upward trend From 1870 to 1921 the purchasing power of hogs shows a strong upward trend and it is conceivable that if it were possible to isolate each of the important factors affecting the price of hogs in Canada from 1870 to 1921 that an upward trend in demand would be found, similar to the trend in demand for beef from 1920 to 1932.

TABLE 4.—FACTORS AFFECTING THE PRICE OF PORK

Year	Price	Supply of pork as % of trend X_2	Demand X_3	Exports of bacon, ham, and pork, millions of lbs. X_4	Exports of lard, millions of lbs. X_5	Readings from respective curves (cents per pound) X_2	X_3	X_4	X_5	Estimated price	Actual price	Difference
1920	26.0	− 9.0	123.5	109.4	7.6	15.9	+5.9	+2.4	+1.9	26.1	26.0	−0.1
1921	17.8	−20.4	93.7	106.1	3.1	19.2	−2.3	+1.8	−0.9	17.8	17.8	0.0
1922	15.6	− 7.0	95.4	100.8	4.8	15.4	−2.0	+0.9	+1.0	15.3	15.6	+0.3
1923	13.1	+ 1.4	100.3	103.6	4.3	13.0	−0.8	+1.4	−0.3	13.3	13.1	−0.2
1924	11.5	+24.5	93.2	128.1	5.3	6.7	−2.4	+5.6	+1.6	11.5	11.5	0.0
1925	15.8	+18.7	95.2	149.8	10.6	8.4	−2.1	+7.5	+2.0	15.8	15.8	0.0
1926	17.1	+ 6.0	103.0	110.0	6.5	11.8	+0.6	+2.7	+1.9	17.0	17.1	+0.1
1927	13.9	+ 8.0	107.7	82.6	4.8	11.3	+2.8	−1.2	+1.0	13.9	13.9	0.0
1928	13.5	+ 4.9	114.6	52.4	1.0	12.1	+5.5	−2.7	−1.4	13.5	13.5	0.0
1929	15.3	− 1.2	122.3	39.0	1.5	13.7	+5.9	−3.2	−1.3	15.1	15.3	+0.2
1930	15.2	−20.2	105.0	20.5	0.2	19.0	+1.6	−3.8	−1.6	15.2	15.2	0.0
1931	9.2	− 9.7	83.1	17.5	4.7	16.1	−3.6	−3.9	+0.8	9.4	9.2	−0.2
1932	5.9	+ 4.3	59.0	46.0	4.9	12.3	−4.6	−2.9	+1.2	6.0	5.9	−0.1
Standard deviation						. . .	. .	. . . . .	. . . . . .	9.36	9.38	
(1) Maximum range						12.5	10.5	11.4	3.6	(cents per pound)		
(2) Total price variation attributed to each factor						37.2	40.4	40.6	15.4			
(3) Percentage of price variations attributed to each factor						28.0	30.0	30.0	12.0			

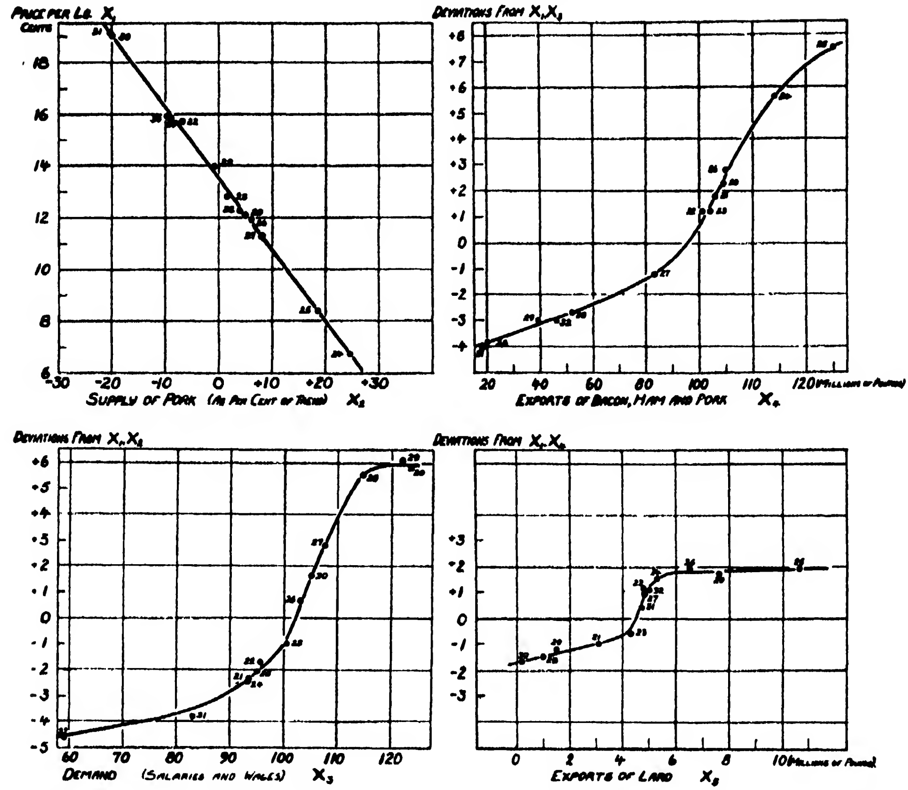

FIGURE 3. Factors affecting the price paid by packers for pork. Canada, 1920 to 1932.

The curve for lard exports indicates the maximum effect of lard exports on the price of pork during the past 13 years to be reached at about 6 million pounds, any increase beyond that point not resulting in any significant increase in prices.

The method of price analysis as presented in this paper is somewhat different from the method followed in most price studies. In order to remove the effect of changing price levels the prices are usually adjusted by dividing by the wholesale index. As a measure of demand, usually some measure of industrial activity has been used instead of wages actually paid. Haas and Ezekiel in a statistical study of factors affecting the price of hogs from 1903 to 1914 (*4*) using the purchasing power of hogs as the dependent variable, found that 32% of the variations in the purchasing power of hogs were due to supply and only 5.7% due to business activity as measured by an index of stock market prices. An index of stock market prices cannot be considered a reliable measure of the total purchasing power available in the country from year to year, as the authors concede in their statement that undoubtedly a great deal of industrial activity is concealed in a rise and fall of the general price index. By using the purchasing power of hogs instead of the actual price of hogs that portion of business activity which is included in changes in the price level is hidden. The 5.7% effect

of industrial conditions very much under-estimates the true influence of the purchasing power of consumers.

Murray (*5b*) in studying the factors affecting the purchasing power of pork in England from 1890 to 1927 found that 85% of the variations in purchasing power could be attributed to the number of pigs in Great Britain, and 3·6% to imports of pork into Great Britain. In the case of English bacon, 44.8% of the variations in purchasing power were attributed to the number of pigs in Great Britain and 21.2% to imports of bacon. In both cases the effect of business conditions, or demand as represented by changes in price levels was not measured.

RELATION OF SUPPLY AND PRICE

In Figure 4 are shown the two supply price curves for beef and pork. The prices have been expressed as percentages of the average for the period and supply expressed as percentages of normal (*i.e.*, trend). It will be noticed that the supply curve for pork has a much steeper slope than for beef, indicating the prices paid by the packers for pork are more sensitive to supply than prices paid for beef, which in turn would indicate the consumption of pork is more sensitive to retail price changes than is the consumption of beef. However further analysis of consumption data and retail prices would be necessary to establish this point.

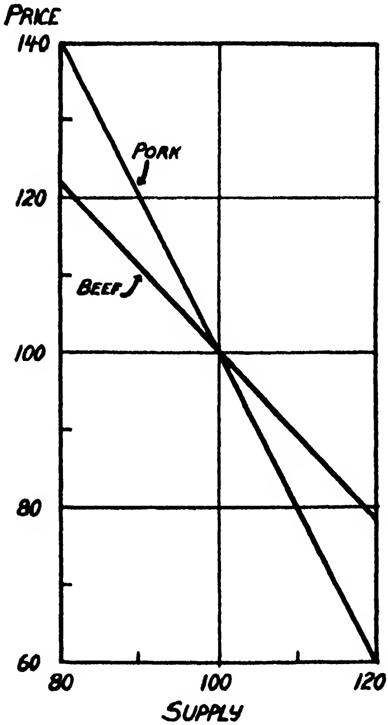

FIGURE 4. The relation of supply and price of beef and pork purchased by packing plants. Canada, 1920 to 1932. When the supply of pork was 20% below normal, prices paid by packers were 40% above normal. When the supply of beef was 20% below normal the prices paid by packers were 22% above normal.

It is of interest to compare the flexibility of prices for beef and pork in Canada, the United States and Great Britain. During the post-war period a supply of pork 20% below normal in Canada resulted in the packers paying a price 40% above normal; in the United States during the period 1890 to 1914 such a decrease resulted in prices 21% above normal at Chicago; in Great Britain during the period from 1890 to 1927 (omitting the years 1915 to 1921) a supply of home produced pork 20% below normal made wholesale market prices 22% above normal. For beef, a supply 20% below normal in Canada resulted in the packers paying a price 22% above normal during the post war period; in the United States from 1890 to 1914 a supply 20% below normal resulted in prices at Chicago 17% above normal and prices on the farm 39% above normal; in Great Britain from 1892 to 1919 a supply of cattle 20% below normal resulted in a price 20% above normal.

The flexibility of prices in the three countries, as disclosed in Table 5, is not exactly comparable as the prices used in the United States and Great Britain were both expressed in terms of purchasing power. In the case of the United States the period studied was before the war, and for Great Britain very few post-war years were included. If both these studies were repeated for the period 1920 to 1932 the price changes would probably have been more violent because of the relatively greater increase in the costs of distribution compared with the prices of beef and pork.

Some indications of the relative position of the livestock industry in Canada under conditions of a large or a small supply can be obtained by use of the data in Table 5. For a supply of pork 80% of normal the packers

TABLE 5.—EFFECT OF CHANGES IN THE SUPPLY ON PRICES PAID FOR BEEF AND PORK IN CANADA, UNITED STATES AND GREAT BRITAIN

Commodity	Supply 20 per cent: below normal — Per cent that prices were: above normal	Supply 20 per cent: above normal — Per cent that prices were: below normal
PORK:		
Canada. 1920-1932. Prices paid by packers	40	40
United States*. 1890-1914. Prices paid at Chicago for West winter hog pack. Nov.-Feb.	21	15
Great Britain.† 1890-1914 and 1922-1927. Prices paid for home produced pork	22	15
BEEF:		
Canada. 1920-1932. Prices paid by packers	22	22
United States*. 1890-1914. Prices paid at Chicago	17	12
United States farm prices	39	24
Great Britain.† 1892-1919. Prices paid on the London market for first quality beef	20	14

*United States data from "Inter relationships of supply and price, p. 112, Cornell University, Agricultural Experiment Station, Bulletin 466. March, 1928

†Data for Great Britain from "Factors affecting the prices of livestock in Great Britain, p. 69 and 149. University of Oxford, Agricultural Economics Research Institute. 1931.

paid a price of 140% of normal. The total value may therefore be represented by 80% of 140, or 112. For a supply of pork 120% of normal they paid a price 60% of normal, or a total value of 72. Similarly for a supply of beef 80% of normal they paid 98 and for a supply 120% of normal they paid 94. In both cases the gross amount paid was less for the large supply than for the small supply. Because freight and commission would be less for the small amount than for the large amount, the farming community received considerably more for the small amount, than for the large supply, besides having lower total costs for the small amount. This is chiefly due to the approximate unit elasticity of retail demand for beef and pork indicated in the first part of this paper. That is to say there is strong evidence that total consumer expenditure for meat tends to contract and

expand almost proportionally with incomes irrespective of the amount consumed, or the amounts purchased by the packers.

Any remarks on the relation between supply and gross farm value of any commodity must go further than the mere statement that small supplies of a given commodity return the farmer larger gross receipts than a large supply. Timoshenko, using data for the United States (*6*) has indicated that a high ratio of agricultural prices to industrial prices often precedes or is coincident with a business recession. On the other hand a low ratio of agricultural to industrial prices generally precedes or coincides with a business revival. He also shows that the high ratio of agricultural to industrial prices is often caused by small crops from which gross receipts from farm sales are usually at a high level. The low ratio of agricultural to industrial prices is coincident with large crops when the gross receipts of farmers are smaller. From his study it appeared that business recession was coincident with high agricultural purchasing power, and revival coincident with low agricultural purchasing power.

This leads one to believe, that with demand remaining the same, although in periods of small supply of crops or livestock the gross farm income is higher than in periods of large supply, the repercussions on industry as a whole are decidedly unfavourable. In periods of small supply all branches of the systems of transportation and distribution of agricultural commodities undoubtedly experience a comparatively low income. For that reason industrial purchasing power arising from the processing and distribution of agricultural products is considerably lower than when agricultural production is at a high level. This purchasing power caused by a small volume of agricultural production is ultimately reflected back in a reduced demand for agricultural products. In the long run the minimum of deviations from trend of the supply of farm products would be most beneficial to agricultural and non-agricultural groups.

SUMMARY

1. Total annual expenditures by urban consumers in Canada for all meats tend to vary almost directly with changes in the demand for these products as indicated by annual totals of wages and salaries.

2. From 1920 to 1932 annual changes in prices paid by all packing plants in Canada for beef and veal and pork have been largely determined by changes in domestic demand as represented by total per capita wage and salary payments of the urban population. For beef and veal domestic demand was responsible for three times as much price variation as supply. Domestic demand, supply and exports were about of equal importance as price making factors in the case of pork.

3. Prices paid by packing plants for pork were more sensitive to supply than prices for beef.

4. Supply price curves for beef and veal, and pork indicate that, other things being equal, farmers as a group receive more gross income from a small supply than from a large supply.

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REFERENCES

1. BEAN, L. H. Measuring the effect of supplies on prices of farm products. Jour. of Farm Ec. *15* : 2, 360-362. 1933.
2. ————. (a) A simplified method of graphic curvilinear correlation. Jour. of Am. Stat. Asscn. Dec. 1929. (b) Application of a simplified method of graphic curvilinear correlation to problems in acreage and yield variation. Jour. of Am. Stat. Asscn. Dec. 1930.
3. EZEKIEL, M. and L. H. BEAN. Economic bases for the Agricultural Adjustment Act. U.S.D.A. pp. 28-29d. Dec. 1933.
4. HAAS, G. C. and M. EZEKIEL. Factors affecting the price of hogs. U.S.D.A. Bull. 1440, p. 36. Nov. 1926.
5. MURRAY, K. A. H. (a) Factors affecting the prices of livestock in Great Britain. p. 71. Agr. Ec. Res. Inst. Oxford University. 1931. (b) p. 141.
6. TIMOSHENKO, V. P. The role of agricultural fluctuations in the business cycles. Michigan Business Studies *2* . 9, 1. Univ. of Mich. June 1930.

Résumé

L'effet de la demande sur la détermination des prix du bœuf et du porc au Canada de 1920 à 1932. E. C. Hope, Professeur-adjoint de l'exploitation de la ferme, Université de la Saskatchewan.

Le montant total dépensé annuellement sur l'achat de toutes les sortes de viandes par les consommateurs urbains au Canada tend à varier presque directement avec les changements qui se produisent dans la demande pour ces produits, indiqués par les totaux annuels payés en gages et en salaires. De 1920 à 1932, les changements annuels dans les prix payés par toutes les salaisons au Canada pour le bœuf, le veau et le porc ont été réglés en grande partie par les changements de la demande domestique, influencés par le montant total payé en gages et en salaires à la population urbaine. Pour le bœuf et le veau la demande domestique a eu trois fois plus d'effet que l'offre sur la variation de prix. La demande domestique, l'offre et les exportations avaient à peu près une importance égale au point de vue de l'effet exercé sur les prix dans le cas du porc. La quantité offerte a exercé plus d'effet sur les prix payés aux salaisons pour le porc que sur les prix payés pour le bœuf. Les courbes de prix pour le bœuf, le veau et le porc indiquent que dans des circonstances égales les cultivateurs, en tant que groupe, tirent toujours un plus gros revenu brut d'un petit approvisionnement que d'un gros approvisionnement.

INVESTIGATIONS ON BLACK KNOT OF PLUMS AND CHERRIES, II.

THE OCCURRENCE AND SIGNIFICANCE OF CERTAIN FUNGI FOUND IN ASSOCIATION WITH *DIBOTRYON MORBOSUM* (*SCH.*) T. & S.[1]

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It is a well-known fact that certain fungi occur with certain other fungi in associations varying from apparently perfect symbiosis on the one hand to complete parasitism on the other. During the course of an intensive investigation of black knot several members of the Fungi Imperfecti appeared consistently in isolations from knot tissues. At first these fungi were considered to be possible imperfect forms of *D. morbosum* (Sch.) T. & S. Later, when it had been definitely shown that they bore no genetic relationship to the black knot fungus the significance of their association with the organism causing the disease was investigated. The results of observations and experiments in this connection are reported in the present article.

REVIEW OF LITERATURE

A survey of the literature in connection with studies on black knot shows that various fungi have been found associated with knots. Farlow (*5*) in 1876 reported the fungus *Trichothecium roseum* on knots and expressed the opinion that it was parasitic on exudant gum on the surface of the knot, and later on the knot stroma. Since that time this fungus has been reported frequently on knots and has been considered to be either a parasite or a saprophyte on the knot stroma. Farlow (*5*) also described several other fungi which he found consistently associated with knots. One of these, which has since been named *Hendersonula morbosa* Sacc., was considered by him to be an imperfect stage of *D. morbosum*. Weir (*17*) in 1914 stated that the cankers formed by the black knot parasite on Prunus and Amelanchier are frequently infected by *Fomes igniarius*. This additional irritation, he states, causes the formation of large burls of very irregular shape and of a peculiar structure. He also reported the frequent occurrence of *Nectria cinnabarina* Fr. on knots. Humphrey (*8*) in 1913 reported a pycnidial-producing fungus associated with knots. He claimed to have obtained this fungus from ascospores and concluded that it was genetically connected with *D. morbosum*. Judging from his description and drawings this fungus was undoubtedly a *Coniothyrium* sp., though he did not assign it to this genus.

Heretofore the significance of the occurrence of the various fungi found in association with black knot has received little or no consideration. In other diseases, however, the literature reporting associations of fungi, which vary from symbiosis to pure parasitism is extensive. The parasitism of *Cronartium ribicola* by *Tuberculina maxima* which has been investigated by Tubeuf (*15*) and others in Europe, and recently by Mielke (*11*) in America

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is a good example. Other interesting instances of the same phenomenon are numerous, *e.g.*, the parasitism of ascocarps of Elaphomyces by species of Cordyceps (Gwynne-Vaughan and Barnes (*7*)); also *Trichoderma lignorum* which was found by Weindling (*16*) to parasitize other soil fungi. Various relationships between bacteria and fungi have been reported. Petri (*12*) in 1927 described a bacterium which penetrates and destroys the hyphae of *Phytophthora* and *Pythiacystis* species. Sanzone (*14*) in 1929 reported a bacterium which lives symbiotically within the hyphae and conidia of *Fusarium solani* (Mart.) Sacc. Johnson (*9*) and Bamberg (*1*) investigated fully the antibiosis of certain bacteria to smut fungi. Burkholder and Guterman (*3*) reported an interesting instance of synergism in a bacterial disease of *Hedera helix*. Machacek (*10*) in carrying out extensive work with different pairs of fungi found examples of (*1*) mutual tolerance and (*2*) partial or complete inhibition of one by its associate. Sanford and Broadfoot (*13*) demonstrated that many soil-inhabiting fungi and bacteria were effective in suppressing the pathogenicity of *Ophiobolus graminis*. Fawcett (*6*) in 1931 summarized to date investigations in connection with known mixtures of micro-organisms.

CEPHALOTHECIUM ROSEUM CORDA (TRICHOTHECIUM ROSEUM LINK) ON BLACK KNOTS

This fungus appears consistently each year in July and August on the surface of the conidial-bearing stroma of knots on *Prunus domestica* L. and is readily recognized by its delicate, pink colour (Plate II, Figure 1). It is apparently widespread in its occurrence, having been observed in various parts of Ontario on knots on the cultivated plum at the above-mentioned time of year. It is also present on knots on *Prunus pennsylvanica*, *P. virginiana*, *P. Maacki*, *P. americana* and *P. domestica* in all provinces from Prince Edward Island to Manitoba. Its presence on the knot is restricted in certain cases to localized areas while in others it completely overruns the fruiting surface, the whole knot being covered with the pink mycelium. Monosporous cultures of the organism were obtained and identified as *Cephalothecium roseum*, Corda.

Infection Experiments

In order to ascertain whether or not *C. roseum* is parasitic on stroma of *D. morbosum* knots which appeared macroscopically to be free from the fungus were chosen for inoculation. A summary of these experiments is given in Table 1. The Cephalothecium conidia in a water suspension were applied with an atomizer to the surface of the knots as in experiments 1 and 2, or by means of a camel's hair brush as in experiment 3, or simply transferred in the dry condition also by means of a camel's hair brush as in experiment 4. Checks were made for each experiment. In experiments 1, 2 and 3 all knots were covered with cellophane bags for three to four days. All infection experiments were conducted a short time previous to the appearance of abundant natural infection in order to minimize as much as possible the infection of checks.

It will be observed in Table 1 that all inoculations of knots with *C. roseum* resulted in infection. Within ten days on all knots either certain areas or the complete fruiting surfaces of *D. morbosum* became covered with the pink mycelium of *C. roseum*. This was true even in cases where

TABLE 1.—RESULTS OF INFECTION EXPERIMENTS IN WHICH BLACK KNOTS WERE INOCULATED WITH *Cephalothecium roseum*

Expt. No.	Date	No. of knots		Results
		Inoculated	Check	
1	7.7.31	5	—	Knots covered with pink mycelium ten days later.
		--	5	No change.
2	9.7.32	5	—	Knots showed presence of localized pink areas fourteen days later.
		—	5	No change.
3	12 7.32	6	—	Knots completely covered with pink mycelium ten days later.
		—	6	Two knots showed small pink areas seven days later. In others, no change.
4	5 7 33	10	—	Localized pink areas on all knots fourteen days later.
		—	10	Three knots showed small pink areas ten days later.

spores were painted on the surface of the conidial-bearing stroma without the addition of water. It will also be noted that a few checks became infected. However, they always manifested a lesser degree of infection by *C. roseum* than those artificially inoculated, which indicated that they probably became infected naturally at some time subsequent to the date of inoculation.

Observations which were made on all of the above inoculated knots in November of the year of infection showed in the first place that the pink, mycelial mat had in most cases disappeared, and secondly, that the knots had resumed their normal, dark colour. Moreover, the perithecia of *D. morbosum* had also vanished leaving only a rough, blackened surface on the knots, which on examination proved to consist of the bases of the original perithecia. The perithecial initials already formed at the time of the attack had been destroyed. Check knots not naturally infected with *C. roseum* or other fungi in the intervening time, manifested the presence of a normal number of immature perithecia.

Cultural Investigations

To confirm the results of the infection experiments, and to obtain information regarding the method of parasitism of *D. morbosum* by *C. roseum*, both fungi were grown as associates in cultures.

Petri dishes containing 10 cc. of potato dextrose agar were inoculated first with conidia of *D. morbosum*. After the colonies became about one half inch in diameter they were inoculated with conidia of *C. roseum*. In a few days the colonies of *D. morbosum* became completely covered with the pink mycelium of Cephalothecium. The latter continued to grow while the growth of the Dibotryon colony was permanently arrested.

When Dibotryon was allowed to grow until it filled the Petri dish after which it was inoculated with *C. roseum*, the latter grew readily, produced abundant conidia and covered the dark green conidial mat with

a pink mat of mycelium in a manner very similar to that on the host outdoors (Plate II, Figure 3). In the final set of experiments spores and aerial mycelium of Petri dish colonies of *D. morbosum* were removed and placed in dry, sterile Petri dishes. To these were added suspensions of conidia of Cephalothecium in a small amount of distilled water. The spores of *C. roseum* germinated and produced a fair abundance of mycelium and spores throughout the mass of Dibotryon conidia, while spores of the latter apparently did not even germinate. Numerous examinations of these cultures showed that the mycelium of *C. roseum*, on making contact with that of *D. morbosum*, frequently became enlarged but did not actually invade the hyphae of the latter fungus. Numerous cases were observed in which the spores of *D. morbosum* were half surrounded by hyphal strands of *C. roseum*. Contact between *C. roseum* and hyphae or spores of *D. morbosum* was followed by disintegration of the latter.

The evidence outlined in the above paragraphs strongly indicates that *C. roseum* is an active parasite of the stroma of *D. morbosum*.

Additional Evidence

To follow the development of knots infected naturally by *C. roseum*, in August of each of two years twenty-four knots were chosen and tagged, of which eight showed severe infection, eight moderate infection and the remaining eight appeared to be free from infection by *C. roseum*. In a few cases the checks became infected subsequent to tagging and were then replaced by non-infected ones.

Periodic observations of these knots during the winter revealed essentially the same facts as did the infection experiments. In all cases perithecia developed more abundantly on non-infected knots than on knots infected by *C. roseum* during the previous summer. The majority of these naturally infected knots, subsequent to infection by *C. roseum*, showed the presence of a second fungus, namely, *Monilia* sp., which is discussed later in this article. It should also be mentioned that all check knots did not produce an abundance of perithecia. The numbers of perithecia which matured on different knots varied greatly, but the difference in their development on knots infected by, and on those free from *C. roseum*, was outstandingly apparent (Plate II, Figure 2).

A survey of the weather records for the years 1931 to 1933 inclusive indicated that mean temperatures for the two weeks in July, during which *C. roseum* consistently appeared and established itself in abundance on knots, varied from 73 2° F., in 1931 to 69.3° F., in 1933. Since this fungus is favoured by high temperatures (*4*) the prevalence of high temperature in July probably contributes to its regular appearance during that month.

Conclusions

As a result of the foregoing experiments and observations the following conclusions were reached. Each summer, beginning in July, *C. roseum* establishes itself on knots as an active parasite of the conidial-bearing stroma of *D. morbosum*. Apparently the ability of this fungus to parasitize other fungi is not restricted to *D. morbosum*. As early as 1909 Whetzel (*18*) reported *C. roseum* to be parasitic upon the fructifications of *Scleroderma vulgare*. Böning (*2*) also, in 1933, in an investigation of *Sclerotinia sclerotiorum* (Lib.) de Bary, states that "the sclerotia of this fungus are

liable to infection by *C. roseum*, which may play quite an important part in the reduction of infective material in the soil during seasons of alternating dry and wet periods."

In culture *C. roseum* appears to be definitely antagonistic to *D. morbosum*, the growth of the latter being permanently arrested, subsequent to the introduction of *C. roseum*. Furthermore, when *C. roseum* is grown in association with *D. morbosum* in Petri dish cultures the hyphae and conidia of the latter are frequently disintegrated after contact with the mycelium of *C. roseum*.

Records of the periodicity of *C. roseum* on knots outdoors would indicate that its consistent attack on *D. morbosum* in July can be attributed in part to the high temperatures which prevail at that time. One highly important practical result of the parasitism of the conidial stroma of *D. morbosum* by *C. roseum* is the consequent reduction in the number of mature perithecia developed.

CONIOTHYRIUM SPECIES ON BLACK KNOTS

During the present investigation of black knot a *Coniothyrium* sp. (probably identical with the species found by Humphrey (*8*)) has been constantly isolated from knot tissue. As Humphrey claimed this fungus to be an imperfect stage of *D. morbosum* and since the observations mentioned above seemed to corroborate this conclusion, a careful investigation of this phase was undertaken.

Isolations

Numerous isolations were made from bud and bark surfaces to find out if the *Coniothyrium* sp. was of general occurrence on the host or was confined strictly to knot tissues. Isolations from knots were made by cutting surface-sterilized plugs of tissue either from the surface or from the interior, and transferring them to tubes or Petri dishes containing potato dextrose agar.

In making isolations from branches a scalpel was scraped lightly over the surface of the branch and then dipped in a drop of sterile water on a slide. This mixture was thoroughly macerated, after which loopfuls were streaked over the surface of potato dextrose agar in Petri dishes. Examinations of these streaks were then made microscopically and single spores, chlamydospores and bits of mycelium were readily cut out and transferred to tubes.

A summary of the isolations in which *Coniothyrium* sp. was obtained during the period 1929 to 1933 is given in Table 2.

It should be pointed out that in isolations from knot swellings in their earliest visible stages *D. morbosum* alone was isolated when external tissues were removed. In all other cases, however, as will be observed from an examination of Table 2, the *Coniothyrium* sp. appeared in isolations from tissues of knots in various stages of development at all seasons of the year. It was isolated frequently not only from tissues in the swollen portion of the knot proper, but also at the edge of the knot where swollen tissues merge into those normal in size. In fact this fungus was found to be so universally present on black knots that when isolations were made from any single knot the *Coniothyrium* sp. consistently appeared in some or all of the cultures, associated with the conidial stage of *D. morbosum*.

TABLE 2.—SUMMARY OF ISOLATIONS OF *Coniothyrium* SP. FROM DIFFERENT HOST MATERIALS

Time of isolation	Materials used in isolations	Coniothyrium / Total no. of isolations
Aug. and Sept.	Tissue from incipient swellings on current season twigs. External tissues not removed.	43/57
Throughout year	Tissue from swollen areas at boundaries of knots.	274/292
Throughout year	Tissue from all parts of knot proper.	62/66
June, July and Aug.	Scrapings from conidial-bearing stroma of knot.	23/23
Jan., Feb. and March	Scrapings from perithecial-bearing stroma of knot.	35/38
April and May	Vaselined slides set up in spore traps at short distances from mature black knots.	14/200
Throughout year	Scrapings from apparently healthy plum, sour and sweet cherry, peach, pear and apple buds and branches.	52/52
Nov. to March	Monochlamydospores found on surface of twigs of *Prunus domestica* and *P. persica*.	36/275

It will be observed in Table 2 that *Coniothyrium* sp. was isolated on 36 occasions from monochlamydospores which were found on the surface of branches of *P. domestica* and *P. persica*. On 52 occasions it was isolated from the bark-surfaces of various fruit trees. No effort was made to ascertain in what form the fungus was present in these latter instances. Undoubtedly some grew from chlamydospores and some from mycelium, while others possibly developed from conidia. It should be mentioned in this connection that *Coniothyrium* sp. was not the only fungus isolated from chlamydospores and mycelium on the bark of various fruit trees. The others, however, will be dealt with in a separate article.

The fact that *Coniothyrium* sp. was isolated from the surface of apparently normal branches not only of plum but also of numerous other hosts indicates that it probably is more or less ubiquitous in nature and its habitat is not limited to black knots.

Description of Fungus

Since in the genus Coniothyrium it is almost impossible at the present time to identify species other than by their limitations to certain hosts, and because this method of identification is entirely unsatisfactory, a specific name has not been assigned to the fungus reported in this article. However, a careful description of the species as it appears on potato dextrose agar, as well as its habitats are given below.

***Coniothyrium* sp.:** Aerial mycelium of young colonies white, sometimes turning to a decidedly pink colour, and later turning brown commencing in the central

portions. The brown mycelium appears in some cases in radial bands and in others diffuses regularly from the centre of the colony (Plate I, Figure 3). Later, pycnidia develop, appearing first in older parts of the colony. Colonies attain a diameter of approximately 40 mm. in seven days in Petri dish cultures incubated at 68–70° F. Pycnidia spherical to compressed with definite, circular ostioles, dark brown, usually superficial on substratum, single or more frequently gregarious, walls membranaceous, in old cultures frequently exuding gelatinous spore masses, the shiny surfaces of which impart to the colony a somewhat mottled appearance, 150–515 μ in diameter (not including the somewhat extended ostioles); spores in mass inky black, seen singly darkly olivaceous, mostly ovoid but varying from short cylindric to pyriform, irregularly guttulate 3 84–7.6 × 2 8–3 8 μ. Habitat: Isolated consistently from all but very young black knots, also from the buds and bark of *Prunus domestica*, *P. virginiana*, *P. pennsylvanica* and *P. cerasus*, *Pyrus malus* and *P. communis*.

Chlamydospore Formation

Following the discovery that a proportion of the cultures of monochlamydosporous origin were the *Coniothyrium* sp. which was consistently isolated from knots, a cultural investigation was undertaken to find out if the life cycle included such a stage. The fungus was grown on various media under different conditions of temperature and moisture. In all cases only pycnidia and pycnospores of *Coniothyrium* sp. developed. When, however, a bacterial organism also isolated from the surface of the bark antagonistic to *Coniothyrium* sp. was introduced into a Petri dish culture at some distance from the latter, chlamydospores developed in the mycelium nearest the bacteria (Plate II, Figure 7). This confirmed the evidence obtained from the isolations and indicated that the production of chlamydospores may frequently be a normal stage in the life cycle of this organism.

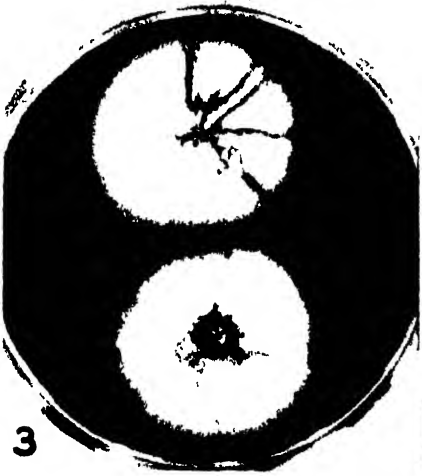
Evidence of Two Strains of *Coniothyrium* sp.

During the course of this phase of investigation the occurrence of two morphologically distinct strains of Coniothyrium was established. These two strains, tentatively designated A and B, were isolated at different times from knots on various hosts and no particular limitations regarding their occurrence was observed except that strain A was isolated much more frequently from *P. domestica* than was strain B. On potato dextrose agar strain A may be distinguished from strain B by its slightly more rapid growth, by a later and usually less abundant development of pycnidia as well as by the dark brown mycelium radiating from the centre of the colony (Plate I, Figure 3). Besides, strain B is usually somewhat more pink in culture than strain A.

The Association of *Coniothyrium* sp. with *D. morbosum* in Culture

The *Coniothyrium* sp. and the conidial stage of *D. morbosum* were grown together on potato dextrose agar to note the effect (if any) of the one fungus on the other. Up to the point of meeting of the two fungi apparently no inhibitory effect was exerted by one organism on the other. However, following contact of the organisms, *D. morbosum* showed no further development and almost invariably was encroached upon by the *Coniothyrium* sp. On the portion of the colony of *D. morbosum* overrun by the *Coniothyrium* sp. an abundance of pycnidia of the latter organism frequently developed.

Authentic evidence of the parasitism of *D. morbosum* by the *Coniothyrium* sp. was not obtained in culture.



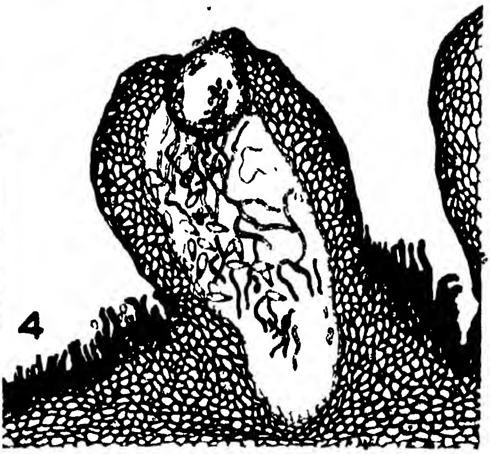


PLATE I

FIGURE 1. The extreme case of callus formation on artificially injured check branch of *P. cerasus*.

FIGURE 2. Branch of *P. cerasus* three months after inoculation with *Coniothyrium* sp. Note swollen area around point of inoculation.

FIGURE 3. Colonies of *Coniothyrium* sp., upper, strain A, lower, strain B.

FIGURE 4. Drawing of longitudinal section of perithecium of *D. morbosum* illustrating the production of pycnidia by the *Coniothyrium* sp. within the perithecia of the former fungus.

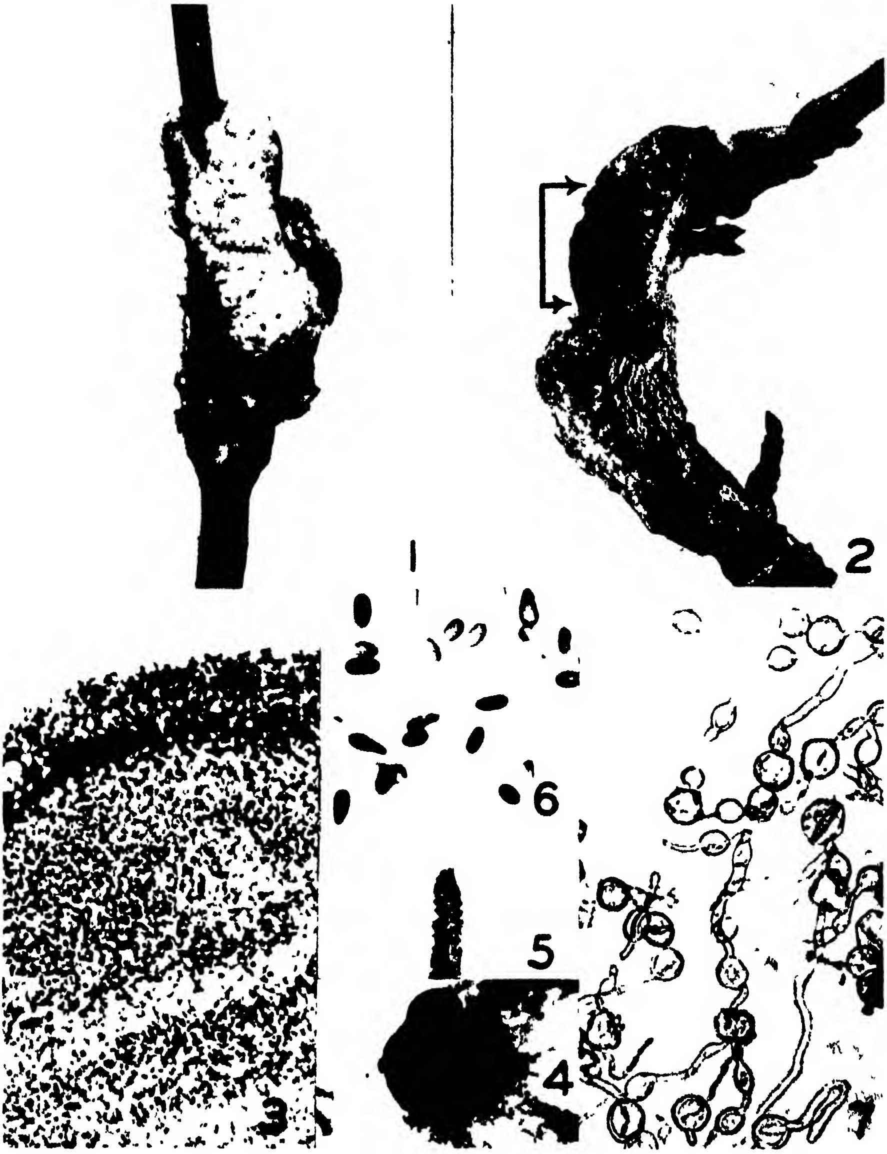


PLATE II

FIGURE 1. *C. roseum* parasitizing the conidial fructification of *D. morbosum* in July.

FIGURE 2. Appearance of a knot in April parasitized previous summer by *C. roseum* except in region indicated by arrows. Note presence of perithecia in non-parasitized region only.

FIGURE 3. Photograph showing *C. roseum* growing on surface of conidial stage of *D. morbosum* in Petri dish culture.

FIGURE 4. Pycnidium of *Coniothyrium* sp. × 55.

FIGURE 5. Photomicrograph of tip of "spore tendril" recently exuded from pycnidium of *Coniothyrium* sp. × 450.

FIGURE 6. Photomicrograph of pycnospores of *Coniothyrium* sp. × 710.

FIGURE 7. Photomicrograph of chlamydospores of *Coniothyrium* sp. × 450.

Evidence Obtained from Sections of Black Knots

To obtain more complete information concerning the habits of the *Coniothyrium* sp. in its relation to black knot, sections were made of knots in various stages on *Prunus domestica*, *P. virginiana* and *P. pennsylvanica*. Sections were obtained with the use of a sliding microtome and were usually stained in cotton blue. Examinations of these sections showed that very soon after the external tissues of young knots became broken, mycelium appeared in these tissues, quite different in character from that of *D. morbosum*, which is easily recognized by its characteristic phalangial aggregates of hyphae. Examinations of numerous other sections showed that pycnidia of the *Coniothyrium* sp. were present on knots at any time after the first appearance of conidia of *D. morbosum* in the summer and even after the perithecia were fully mature. Pycnidia could be found anywhere within the fruiting area of the knot and were frequently half-imbedded among the conidiophores and conidia. During the fall and winter pycnidia of Coniothyrium were abundant on the perithecial stroma of *D. morbosum* on *P. pennsylvanica* in particular, and mycelium frequently penetrated the immature perithecia. In more advanced stages mature pycnidia of *Coniothyrium* were observed actually within almost empty perithecia from the mouths of which their ostioles protruded (Plate I, Figure 4).

Infection Experiments

Numerous infection experiments involving *Coniothyrium* sp. were conducted during a period of four years. Many inoculations were made on healthy branches of *P. domestica* and *P. cerasus*, primarily to discover whether this organism alone was capable of inducing the formation of knots. During the past two years numerous knots were also inoculated in the hope of obtaining more information concerning the habits of the *Coniothyrium* sp. In all inoculations a water suspension of pycnospores belonging to either one or both strains was applied either with an atomizer or a camel's hair brush. Twigs and branches were surface-sterilized with mercuric chloride and washed with sterile water before inoculating. Checks were made for all infection experiments except those involving knots in which case ordinary knots had to be used. Since space does not permit a complete description of all infection experiments carried out with this organism a small number of representative experiments and the results obtained are summarized below in Table 3.

In the first place, from Table 3, it is readily seen that in no instance did typical black knots develop as a result of inoculation with *Coniothyrium* sp. When branches of *P. domestica* and *P. cerasus* were injured and inoculated, however, they did develop swollen areas around the points of inoculation during the current season of growth (Plate I, Figure 2). Pycnidia finally developed within the crevices of the swollen areas on inoculated branches. Checks, on the other hand, which were made under precisely identical conditions did not manifest similar swellings. On branches of the above-mentioned hosts which were uninjured but inoculated, no swellings developed except very small ones where tiny twigs were pruned. It will also be observed that brown, somewhat elevated lesions, variable in size, developed on current season twigs which were inoculated and covered for two weeks with cellophane bags. It should be mentioned, however, that current season twigs inoculated in a manner

TABLE 3.—INFECTION EXPERIMENTS WITH *Coniothyrium* SP. ON BRANCHES OF *P. domestica*

Date of experiment	No. of inoculations	Host	Treatment	Results
12.5 31	8	Branches several years old, *P. domestica.*	Injured to xylem with scalpel and bound for two weeks with moist blotting paper enclosed with wax paper.	Three months later all branches somewhat swollen in vicinity of inoculations. Pycnidia of *Coniothyrium* sp. in crevices.
12 5 31	8	Branches several years old, *P. domestica.*	Uninjured except for pruning of tiny twigs. Bound for two weeks with moist blotting paper enclosed with wax paper.	Three months later all inoculated branches were not affected except for tiny swellings which appeared around some pruning wounds. Pycnidia in crevices of bark.
12.5.31	8	Checks	Checks (Injured)	Three months later all checks calloused but not swollen.
20.5 32	4	Current season twigs Reine Claude plums.	Spores atomized on twigs and twigs covered with cellophane bags for two weeks.	Two months later numerous brown lesions several mms. in diameter appeared on twigs.
20.5 32	4	Checks	Checks	Two months later all checks showed no change.

similar to that described above except that they were not covered with bags developed no, or relatively few, brown lesions which were smaller in size, usually 1 or 2 mm. in diameter.

A noteworthy feature of the inoculations which developed swollen areas was the fact that the swellings did not continue to increase in size subsequent to the year in which they were made. After three, and in some cases, four years, these swollen areas are still noticeable but are evident more by their character than their size. Areas in the vicinity of the swellings are darker in colour than surrounding bark and creviced longitudinally. After three years pycnidia of *Coniothyrium* sp. are still present within the crevices. Reisolations have been made at intervals from many of these inoculations and they seldom failed to yield *Coniothyrium* sp. The fact that no swellings developed on uninjured branches which were inoculated with *Coniothyrium* sp. would indicate that the fungus was unable to penetrate the periderm layers covering the inner host tissues. When inoculations were made on current season twigs later than May the brown lesions referred to above did not develop, though the fungus was frequently reisolated several months later from these twigs. Examinations of twigs on which the brown lesions developed revealed mycelium within the boundaries of the lesions between the cuticle and the epidermis. Later in the fall these lesions were apparently cut off by a layer of periderm which formed beneath the lesions. During the winter they gradually lost

their individuality and though the fungus was still present their locations were marked only by the absence of cuticle on the infected areas.

With reference to the experiments in which knots were inoculated with *Coniothyrium* sp. inconsistent results were obtained. The chief difficulty encountered here was the impossibility of finding knots entirely free from this fungus and, therefore, of making comparisons. They did, however, confirm one point of evidence previously obtained from the study of sections of knots, namely, that during the latter part of the life cycle of knots *Coniothyrium* sp. becomes parasitic on the stroma of *D. morbosum.* More abundant pycnidia were present on inoculated than on non-inoculated ones, and occasionally distinct evidence of parasitism was apparent.

The above experiments and observations prove that this *Coniothyrium* sp. hitherto reported to be the pycnidial stage of *D. morbosum* and found closely associated with all except the most incipient stages of black knots, does not belong genetically to *D. morbosum.* The following reasons are submitted for arriving at the above conclusion:

1. Cultures from ascospores and conidia of *D. morbosum* never yielded *Coniothyrium* sp.
2. Cultures from internal tissues of young knots when they were first visible as minute swellings on current season twigs did not yield *Coniothyrium* sp. although they did yield the conidial stage of *D. morbosum.*
3. Cultures of *Coniothyrium* sp. always produced pycnidia and pycnospores, and never conidia or perithecia of *D. morbosum.*
4. *Coniothyrium* sp. was isolated not only from knots but also from various other parts of *P. domestica* and other hosts.
5. Inoculations of twigs of *P. domestica* with pycnospores of *Coniothyrium* sp. gave positive infection but did not result in the development of typical black knots in contrast to similar inoculations with *D. morbosum.*

In summarizing the results of the observations and experiments on *Coniothyrium* sp. and its relation to black knot the following conclusions have been reached.

Coniothyrium sp. becomes associated with black knots very early in their development, probably as soon as the knot becomes visible to the eye as a small swelling on a current season twig. At this stage the cuticle of the host is broken and frequently the epidermis as well, making an admirable resting place for any fungus. Not until this time do the two fungi become intimately associated. Subsequent to this developmental stage apparently all knots during part or all of the remainder of their life cycles have *Coniothyrium* sp. associated with them. It is probable that the mycelium which has been observed to be distinct from that of *D. morbosum* in sections of young knots belongs to *Coniothyrium* sp. since this fungus is the only one which has been consistently isolated along with *D. morbosum* at this stage.

At all times subsequent to the production of conidia by the knot the pycnidia of *Coniothyrium* sp. have been observed situated either superficially or among the conidiophores of *D. morbosum.* Numerous sections of knots in all stages of development have indicated that actual parasitism

of the stroma of *D. morbosum* by the *Coniothyrium* sp. does not take place until towards the following spring when the perithecia are maturing. Occasionally immature perithecia appear to be invaded by the fungus and frequently a degeneration of the contents is followed by the formation of pycnidia of the *Coniothyrium* sp. within the walls of the perithecia.

MONILIA SP. ON BLACK KNOTS

For the past three years a fungus producing a white mat of mycelium has been observed on knots which were first attacked by *Cephalothecium roseum*. Occasionally the fungus also appeared on knots which appeared to be free from *C. roseum*. Many unsuccessful attempts were made to determine the identity of the fungus as it appeared on the host. In pure culture, however, it proved to be a species of Monilia and it has been isolated on numerous occasions since September 1931 from *Prunus domestica*, *P. pennsylvanica* and *P. virginiana*. Since this fungus did not appear to play a particularly significant rôle in relation to black knot its action was not investigated in detail. When the *Monilia* sp. was grown in Petri dish cultures in association with *D. morbosum* each exhibited a tolerance towards the other. Under such circumstances the *Monilia* sp. ultimately covered the dark mat of conidiophores and conidia of *D. morbosum* with its loose, cottony, white mycelium and produced an abundance of conidial chains superficially.

Because of its frequent occurrence on knots in the summer, and judging by its cultural reactions referred to above, it may be considered with a measure of justification to be sometimes parasitic on the stroma of *D. morbosum*.

HENDERSONULA MORBOSA SACC. ON BLACK KNOTS

This fungus was discovered first on the stromata of black knots by Farlow (5) in 1896. He interpreted it as a pycnidial stage of the organism causing black knot.

H. morbosa was first isolated during the present investigations on May 29, 1930, from a perithecial maceration of a knot on *Prunus cerasus* collected in the Georgian Bay district. Since that date it has been isolated on numerous occasions from knots on both *P. domestica* and *P. cerasus* collected in the above-mentioned district.

Close examinations of these knots showed that acervuli of *H. morbosa* were situated among the perithecia of *D. morbosum*. Cultures of *H. morbosa* were obtained only from conidia of the same fungus and never from ascospores of *D. morbosum*.

Branches of both *P. domestica* and *P. cerasus* were inoculated with *H. morbosa* in a manner similar to that used with *Coniothyrium* sp. (see infection experiments). In no instance did knots develop. However, a specific reaction was manifested by all inoculated branches in the form of a copious exudate of gum around each point of inoculation. Checks, on the other hand, never exhibited this reaction.

After it had been demonstrated that *H. morbosa* was not genetically connected with *D. morbosum* and that it was incapable of producing black knots, further investigations of this fungus were abandoned. The observations and examinations of knots on which *H. morbosa* was present would,

however, indicate its ability to act as a parasite on the stroma of *D. morbosum.*

SPHAERONEMA SP. ON BLACK KNOTS

Incidental to the present investigations, examinations of knots kindly supplied by H. T. Güssow, Dominion Botanist, revealed pycnidia of a member of the Fungi Imperfecti on the perithecial-bearing stroma of *D. morbosum.* The fungus was identified as a species of Sphaeronema.

Dr. Güssow first collected knots on which this fungus was present in 1909 near St. Johns, Newfoundland, on *Prunus pennsylvanica.* Since that time he has collected similar specimens in the same area as well as at Norway

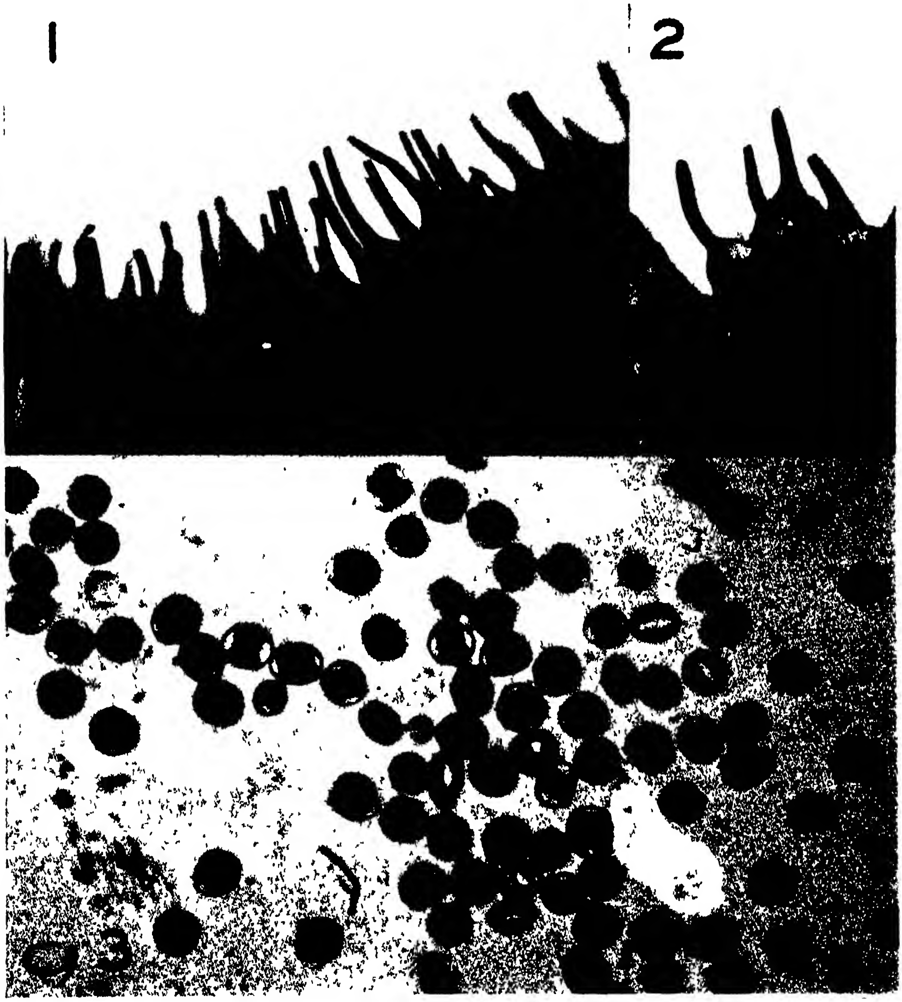


PLATE III

FIGURES 1 and 2. *Sphaeronema* sp. fruiting on stroma of *D. morbosum.* × 40. Note long necks on pycnidia.
FIGURE 3. Pycnospores of *Sphaeronema* sp. × 650.

Bay, Ontario, on the same host. F. L. Drayton has observed the same fungus on knots on *P. domestica* collected in the Adirondack Mountains.

On the specimens examined, the pycnidia of the *Sphaeronema* sp. were present in great abundance both superficially and among the perithecia of *D. morbosum* to the extent that in some cases they entirely replaced the perithecial-bearing stroma of the latter fungus (Plate III). In these instances parasitism of the stroma of *D. morbosum* by the *Sphaeronema* sp. was indicated, but since no cultures of the latter species were obtained and since no specimens of a similar nature were observed in the Niagara Peninsula, a definite statement cannot be made in this connection.

OTHER FUNGI ISOLATED FROM KNOTS

Other fungi such as *Fusarium* sp., *Alternaria* sp., *Nectria* sp., *Sporotrichum* sp., *Phoma* sp., *Cladosporium* spp. and a Torula-like fungus were frequently isolated from knot stromata, in particular from those bearing conidiophores and conidia. Some or all of these fungi may possibly be consistently parasitic on the stroma of *D. morbosum*. The investigation of this phase was not sufficiently intensive, however, to determine the importance of any other than the more common associates.

DISCUSSION

The outstanding feature of the above investigation on black knot is the demonstration of a measure of biologic control exerted by *C. roseum* in reducing materially the number of perithecia of *D. morbosum* which develop on any mature knot. The degree of importance which should be attached to this type of control in a consideration of black knot is difficult to evaluate. In many other diseases where a similar phenomenon has been proved it is considered to be relatively unimportant from the practical standpoint. On the other hand the importance of *C. roseum* in the black knot disease was observed in the laboratory plum orchard in a block of check trees which were neither sprayed nor pruned during the past five years.

During the first four years the number of knots occurring on these trees increased quite regularly and during the first three years at least, an abundance of perithecial material was available in the spring. During the same period knot infection by *C. roseum* was increasing in direct proportion to the increase in the number of knots until finally practically 100% of the knots were infected by this fungus. During the past year a sharp drop in the number of new knots was noted and the amount of available, mature, perithecial material decreased to the point where to obtain the perfect stage it was necessary to go to other parts of the orchard where there were fewer knots and where infection by *C. roseum* was not so general. This circumstantial evidence substantially confirms that already submitted to the effect that *C. roseum* does cause an important measure of biologic control of black knot.

Another feature of the present investigation of black knot is the observation that a *Coniothyrium* sp., though itself incapable of producing typical black knots, is always found associated with *D. morbosum* in all knots except those in their most incipient stages. It is true that on branches of *P. domestica* which were artificially injured and inoculated with the *Coniothyrium* sp. a certain amount of swelling was induced during the

current season of growth. However, these swollen areas did not continue to increase in size in subsequent years nor did swellings develop on branches of the same host where no infection courts were provided. In addition to its constant association with black knots this fungus has proved to be more or less ubiquitous, having also been found superficially on the bark and buds of many fruit trees.

The above points of evidence would seem to warrant the conclusion that this *Coniothyrium* sp. does not play a limiting rôle in the development of knots. Its universal presence on all except very young knots, as well as the results outlined in the present investigation lead to the conclusion that black knots merely furnish an unusually favourable substratum for this fungus. During the later developmental stages of knots the *Coniothyrium* sp. has been observed to be definitely parasitic on the stroma produced by *D. morbosum.* Therefore, though it must not be referred to in a consideration of the *cause* of the disease, *Coniothyrium* sp. must receive consideration in connection with the normal development and sequence of events which transpire during the life cycle of a knot.

In concluding it is postulated to be a normal occurrence for all black knots to become parasitized at some time in their life cycles by *Coniothyrium* sp. Besides, many are also parasitized by *C. roseum* and other fungi. On the other hand, it must be considered highly extraordinary if one or more of the fungi enumerated in this article are not present on any knot far enough advanced to produce conidia.

While the scope of the investigations of fungi which are parasitic on *D. morbosum,* outlined in this article has been fairly comprehensive it is by no means exhaustive and further studies would probably throw additional light on the phenomenon of infection of black knots by other organisms.

ACKNOWLEDGMENT

Thanks are gratefully extended to Dr. G. H. Berkeley for helpful suggestions at various times in the course of investigation.

SUMMARY

1. *Cephalothecium roseum* Corda appears consistently in July and August every year on the conidial-bearing stroma of *Dibotryon morbosum* (Sch.) T. & S., in many knots on various hosts.

2. Evidence is adduced that in nature *C. roseum* actively parasitizes the stroma of the black knot organism.

3. When *C. roseum* is introduced into a Petri dish culture at some distance from a young colony of *D. morbosum* the growth of the latter is after a few days permanently arrested. *C. roseum,* on the other hand, grows rapidly over the medium and finally parasitizes the colony of *D. morbosum* inducing a disintegration of its mycelium.

4. Observations and infection experiments have indicated that *C. roseum* exerts an important measure of natural biologic control over *D. morbosum.* This is brought about by a destruction of the perithecial initials in the conidial-bearing stroma and is manifested usually by a reduction in numbers, and occasionally by a complete inhibition of perithecia on infected knots.

5. Over a period of four years a species of *Coniothyrium* has been isolated at will from all knots except those in their earliest stages of development. This *Coniothyrium* sp. has also been isolated at all times of the year from the bark and buds of apparently healthy branches of *Prunus domestica, P. cerasus, P. virginiana, P. pennsylvanica* and *P. persica, Pyrus communis* and *P. malus*. Its presence during the winter in the form of chlamydospores on the bark of the above-mentioned hosts has been demonstrated.

6. A description of the *Coniothyrium* sp. is given.

7. The *Coniothyrium* sp. and *D. morbosum* manifested a mutual tolerance toward each other when grown as associates in culture.

8. Infection experiments have demonstrated that this *Coniothyrium* sp. is capable of causing slight swellings but not typical knots, on branches of *Prunus domestica* and *P. cerasus* when infection courts are provided.

9. Evidence is submitted which proves that the *Coniothyrium* sp. is not genetically connected with *D. morbosum*.

10. During the later developmental stages of knots, the *Coniothyrium* sp. has been observed to produce an abundance of pycnidia around and within both immature and mature perithecia of *D. morbosum*.

11. A species of Monilia, *Hendersonula morbosa* Sacc., *Sphaeronema* sp., *Nectria* sp., *Phoma* sp., *Sporotrichum* sp., *Cladosporium* spp., *Fusarium* sp., *Alternaria* sp., and a Torula-like fungus were frequently isolated from black knots. None of these fungi is an imperfect stage of *D. morbosum*.

LITERATURE CITED

1. Bamberg, R. H. Bacteria antibiotic to Ustilago Zeae. Phytopath. *21* : 881-890. 1931.
2. Böning, Karl. Zur Biologie und Bekampfung der Schlerotienkrankheit des Tabaks (*Sclerotinia sclerotiorum* (Lib.) Massee). Phytopath. Zeit. *6* : 138. 1933.
3. Burkholder, W. H. and Guterman, C. E. F. Synergism in a bacterial disease of Hedera helix. Phytopath. *22* : 781-784. 1932.
4. De Oliveira, B. "*Cephalothecium roseum*" Corda. Rev. Agron. (Lisbon), 18 : 3 : 49-63; 4 : 9-67. 1930.
5. Farlow, W. G. Black knot. Bull. Bussey Inst. *24* : 440-453. 1876.
6. Fawcett, H. S. The importance of investigations on the effects of known mixtures of micro-organisms. Phytopath. *21* : 545-550. 1931.
7. Gwynne-Vaughan, H. C. I. and Barnes, B. The structure and development of the Fungi. Cambridge Univ. Press, pp. 158. 1927.
8. Humphrey, J. E. The black knot of the plum. Mass. (Hatch) Agr. Exp. Sta. Rept. *8* (1890) : 200-210. 1891.
9. Johnson, Delia. The antibiosis of certain bacteria to smuts and some other fungi. Phytopath. *21* : 843-864. 1931.
10. Machacek, J. E. Studies on the association of certain phytopathogens. Tech. Bull. No. 7, MacDonald College, McGill Univ. 1928.
11. Mielke, J. L. *Tuberculina maxima* in western North America. Phytopath. *23* : 299-305. 1933.
12. Petri, L. Un batterio parassita di alcune Phytophthoreae. Bol. R. Staz. Patol. Veg. n.s. *7* : 457-464. 1927.
13. Sanford, G. B. and Broadfoot, W. C. Studies of the effect of other soil-inhabiting micro-organisms on the virulence of *Ophiobolus graminis*, Sacc. Sci. Agr. *11* : 512-528. 1931.
14. Sanzone, F. Il *Fusarium solani* (Mont.) Sacc., in simbiosi mutualistica con batterinella determinazione di cancrema unida dei tuberi di patata. Bol. R. Staz. Patol. Veg., n.s. *9* : 170-213. 1929.

15. TUBEUF, C. VON. Uber *Tuberculina maxima*, einen Parasiten des Weymouths kiefern-Blasenrostes. Arb. K. Biol. Land. u. Forstw. *2* : 169-173. 1901.

16. WEINDLING, R. *Trichoderma lignorum* as a parasite of other soil fungi. Phytopath. *22* : 837-842. 1932.

17. WEIR, JAS. R. The cankers of *Plowrightia morbosa* in their relation to other fungi. Note in Phytopath. *4* : 339. 1914.

18. WHETZEL, H. H. A fungus living as a parasite upon another fungus. Ont. Nat. Sci. Bull. *5* : 1909.

Résumé

Recherches sur le Black Knot des pruniers et des cerisiers, II. Manifestation et signification de certains champignons trouvés en association avec le *Dibotryon morbosum* (Sch.) T. et S. L. W. Koch, Pathologiste-adjoint en végétaux, Laboratoire fédéral de pathologie végétale, St. Catharines, Ontario.

Le *Cephalothecium roseum* Corda fait son apparition régulièrement en juillet et en août tous les ans sur les stromas conidiophores de *Dibotryon morbosum* (Sch.) T. & S., dans bien des noeuds sur différents hôtes. Il a été démontré que dans les conditions naturelles le *C. roseum* vit en parasite sur le stroma de l'organisme du noeud noir (Black Knot). Lorsqu'on introduit le *C. roseum* dans une culture sur plat Petri, à quelque distance d'une jeune colonie de *D. morbosum*, la végétation de cette dernière est permanemment interrompue au bout de quelques jours tandis que, le *C. roseum* se développe rapidement sur le milieu et envahit finalement la colonie de *D. morbosum*, provoquant une désagrégation de son mycélium. Les observations et les essais d'infection ont indiqué que *C. roseum* exerce un contrôle biologique naturel important sur le *D. morbosum*. Ce contrôle est provoqué par une destruction des périthèces naissants dans le stroma conidiophore et il se manifeste ordinairement par une réduction du nombre et parfois par une suppression complète des périthèces sur les noeuds infectés. Pendant une période de quatre ans, une espèce de *Coniothyrium* a été isolée facilement de tous les noeuds sauf ceux qui étaient dans leurs premières phases de développement. Cette espèce de *Coniothyrium* a été isolée également, à tout moment de l'année, de l'écorce et des bourgeons de branches apparemment saines de *Prunus domestica*, *P. cerasus*, *P. virginiana*, *P. pennsylvanica* et *P. persica*, *Pyrus communis* et *P. malus*. Sa présence en hiver sous forme de chlamydospores sur l'écorce des hôtes précités a été démontrée. Une description de l'espèce *Coniothyrium* est donnée. Les espèces *Coniothyrium* et *D. morbosum* ont manifesté une tolérance mutuelle l'une envers l'autre lorsqu'elles étaient cultivées ensemble. Les essais d'infection ont démontré que cette espèce *Coniothyrium* peut causer de légères boursouflures, mais non pas de noeuds typiques, sur les branches de *Prunus domestica* et *P. cerasus* lorsque des foyers d'infection sont pourvus. Des preuves sont soumises démontrant que l'espèce *Coniothyrium* n'a pas de parenté génétique avec le *D. morbosum*. Pendant les dernières phases du développement des noeuds, on a constaté que l'espèce *Coniothyrium* produit une abondance de pycnidies autour et en dedans des périthèces non mûrs et mûrs de *D. morbosum*. On a souvent isolé des noeuds noirs des espèces de Monilia, *Hendersonula morbosa* Sacc., *Sphaeronuma*, *Nectria*, *Phoma*, *Sporotrichum*, *Cladosporium*, *Fusarium*, *Alternaria* et un champignon semblable au Torula. Aucun de ces champignons n'est une phase imparfaite de *D. morbosum*.

ZONATION FOR FERTILIZER REQUIREMENTS IN THE NORTHERN PRAIRIES

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INTRODUCTION

A series of fertilizer trials[2] covering the grain producing portion of Manitoba was undertaken during the years 1929, 1930 and 1931, the results of which suggest a zoning for fertilizer requirement of cereals when the drilling-in method is used in the Canadian prairies.

The superiority of the drilling-in method of application and its use in other countries is shown by Richardson (*5*), Dudley (*2*), Truog (*7*), Salter (*6*) and others.

The practice of drilling in fertilizer with the seed, which has proved to be one of the most important contributions to cereal production in Western Canada, was introduced into the West in 1928. Prior to 1928 and at various intervals during the development of the Canadian West, experiments were conducted with the application of commercial fertilizers to cereals and other crops by the broadcast method. The results obtained in general did not indicate sufficient response to cause any considerable extension of these trials, or to warrant the recommendation of fertilizers for general use, until the Australian type of combined grain and fertilizer drill was introduced for experimental use in 1928. The subsequent trials with phosphate fertilizers opened up a new aspect in the fertilization of cereals on the Canadian prairies.

FERTILIZER PROJECT

In 1929 a simple series of fertilizer trials was undertaken in Manitoba by the Junior Co-operators and continued for a three-year period. The trials, which were distributed throughout the grain producing area of the province, were conducted at 130 points in 1929, at 122 points in 1930, and at 70 points in 1931. On each farm duplicate plots of Reward wheat were planted in replicated rod-rows, each one foot apart and with an untreated guard row between each treatment. The fertilizer was applied in drills by hand one inch below the seed at the time of seeding. The treatments included: (*1*) ammoniacal nitrogen; (*2*) nitrate nitrogen; (*3*) phosphate; (*4*) potash; (*5*) ammonia and phosphate; (*6*) ammonia and potash; (*7*) phosphate and potash; (*8*) ammonia, phosphate and potash; (*9*) no fertilizer. The amounts of fertilizer applied were as shown in the accompanying table.

At each point, four replicated rows of each of the nine treatments were harvested. The 36 separate rows were shipped to the University, where they were threshed and the yields and errors for each point were

[1] Soils Division, Department of Agronomy.

[2] The fertilizer trials here reported were conducted by the "Junior Co-operators" and financed by the Educational Department of the Manitoba Wheat Pool co operating with the Soils Division, Manitoba Agricultural College. The writer herewith expresses to the Junior Co-operators his sincere appreciation of the faithful manner in which they carried out their assignments, and especially desires to acknowledge the kindly interest displayed throughout by Mr. C. H. Burnell, President of the Manitoba Wheat Pool, whose energetic co-operation made the project possible Grateful acknowledgment is also made of the assistance and advice given by Dr. C. H. Goulden in connection with the statistical treatment of the data.

AMOUNTS OF FERTILIZER APPLIED*

Kind of fertilizer	Rate per acre in pounds	Pounds of fertilizer ingredients per acre		
		N	P_2O_5	K_2O
Ammonium Sulphate	112½	22½	—	—
Sodium Nitrate	150	22½	—	—
Triple Superphosphate	75	—	33	—
Sulphate of Potash	50	-	—	24
Ammonium Sulphate and Triple Superphosphate	112½ and 75 = 187½	22½	33	—
Ammonium Sulphate and Potassium Sulphate	112½ and 50 = 162½	22½	—	24
Triple Superphosphate and Potassium Sulphate	75 and 50 = 125	—	33	24
Ammonium Sulphate, Triple Superphosphate and Potassium Sulphate	112½ and 75 and 50 = 237½	22½	33	24

*The amounts of fertilizer given per acre were the amounts actually used on an acre basis with the drill rows one foot apart

calculated; all the records from farms having excessively high standard deviations were discarded. The average annual yield for each of the fertilizer treatments on the individual farms was compiled and treated as single replicates or blocks in the yield tables for each of the nine agricultural districts in which the trials were distributed (Figure 1). The records for each of the three years were submitted to an analysis of the variance by Fisher's method (*3*).

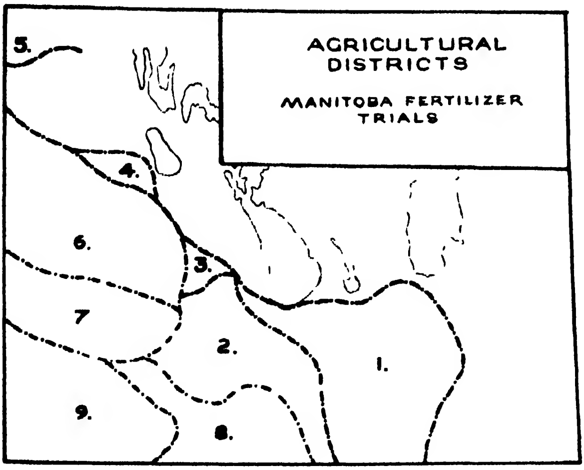

FIGURE 1. Agricultural districts of Manitoba in which fertilizer trials were conducted 1929-1930-1931.

On account of ammonium sulphate being used as the carrier of nitrogen where required in combination, the yields for nitrogen alone in the variance tables were taken from the ammonium sulphate treatments. The nitrate treatments are reported separately.

RESULTS

The results obtained for each of the nine districts are presented in Tables 1 to 3, which show the following by years: Table 1, the average yields of grain in bushels per acre; Table 2, the analysis of variance of the data for each year; and Table 3, the summary of the effect of each element on the yield in bushels per acre.

A graphic representation of the mean yields for the three years in per cent of the general mean of each district, which are tabulated in Table 1, is presented in Figure 2. The graphs in this figure present the yields in

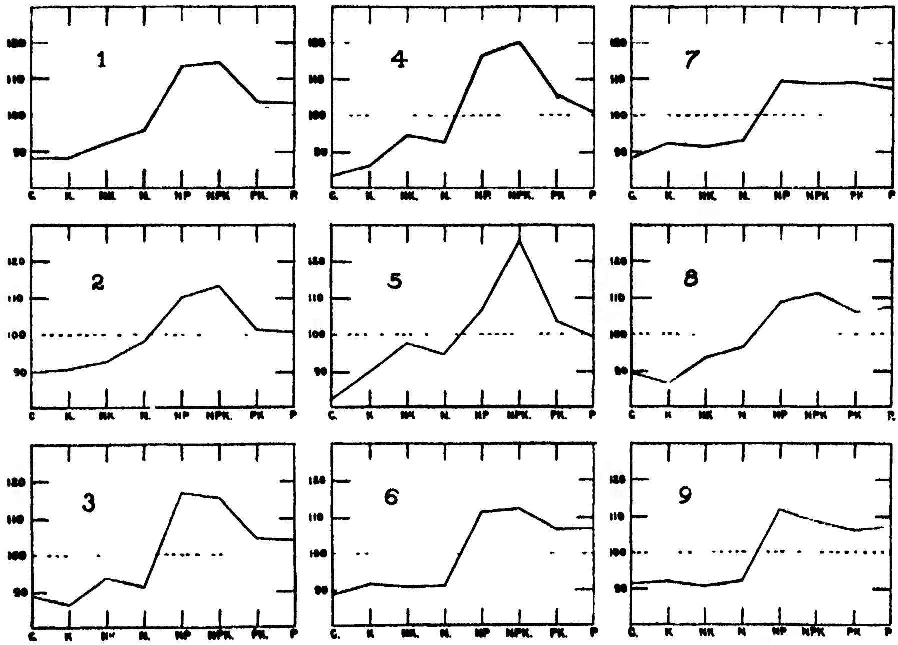

FIGURE 2. Average yields of wheat in percent of each district mean. The large numbers refer to crop districts and the symbols across the base of each graph are in the order of C. K. NK. N. NP. NPK. PK. P. from left to right

per cent of the general mean for each of the treatments in each district in the order of: (*1*) check, (*2*) potash, (*3*) nitrogen and potash, (*4*) nitrogen, (*5*) nitrogen and phosphate, (*6*) nitrogen, phosphate and potash, (*7*) phosphate and potash, and (*8*) phosphate, and arranged from left to right so that the phosphate treatments are shown at the right of each graph. The curves shown in Figure 2 for each of the nine districts may be classified into three types:

(1) Those showing response to phosphate only;

(2) Those showing response to nitrogen and phosphate, and

(3) Those showing response to nitrogen, phosphate and potash.

By arranging the graphs on the map according to districts, a geographical distribution of the three types of curves is apparent (Figure 3). This distribution is definite and specific and is shown in summary form in Table 4. In this summary the average increase or decrease with nitrogen, phosphate and potash was calculated by combining all treatments with and without each fertilizing element by districts. The mean figures are arranged in the table in the order of the geographical occurrence of each district, (A) from south to north, and (B) from east to west.

The figures of the percentage increase in Table 4 (A) show that districts 1, 2 and 3 may be grouped on the basis of similar response. These

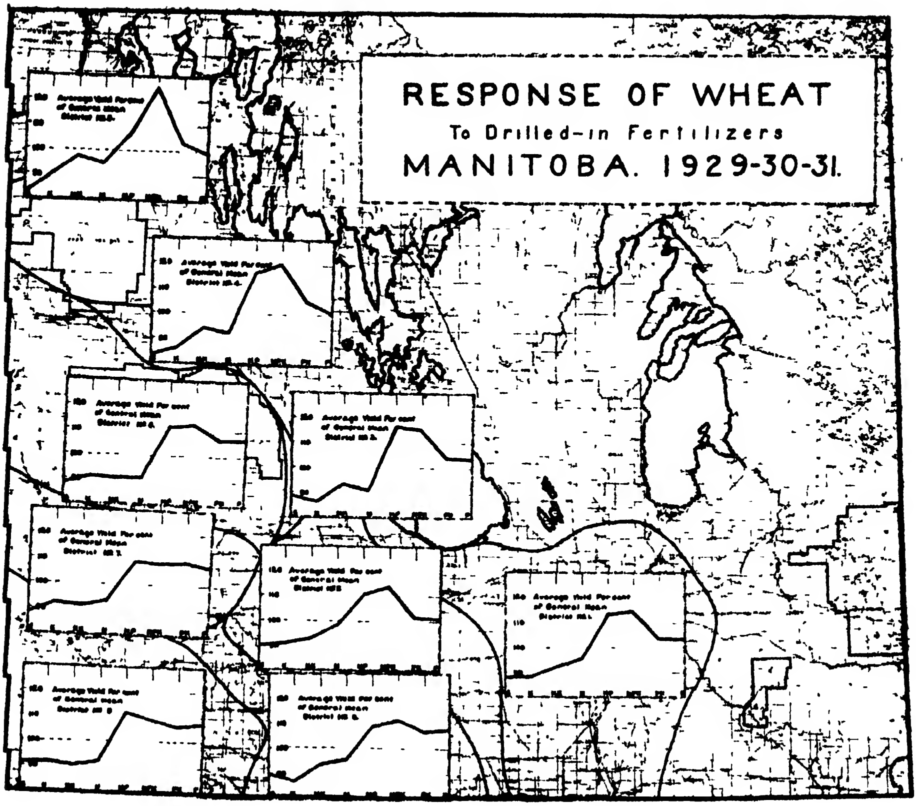

FIGURE 3. Yield-curve charts superimposed over Agricultural district map to show geographical distribution of response. The symbols across the base of each graph are in the order of C. K. NK. N. NP. NPK. PK. P. from left to right.

show significant and marked increase with phosphate, and significant though smaller increase with nitrogen. In the more northerly districts (4 and 5) similar response was obtained with phosphate, but increasing response was secured with nitrogen. In these two districts a tendency to increased yield with the use of potash appears. This increase is slight and barely significant in district 4. In district 5, individual farm records showed significant response to potash especially in 1930, but the limited number of trials in this district and the differential response to potash on different farms resulted in a relatively high standard error. Hence the significance of the average results for the district is lowered. From east to west the percentage figures in Table (B) show a similar response to phosphate throughout, and with no response to potash. The response to nitrogen however, which is significant in the eastern districts (1, 2 and 3) is not apparent in the Western districts (7, 8 and 9).

The analyses of variance given in Table 2 do not show significant interactions of the first order between nitrogen and phosphate, nitrogen and potash, or phosphate and potash. Neither is there any apparent second order interaction with the combination of the three elements. On

TABLE 1.—MEAN YIELDS OF GRAIN IN BUSHELS PER ACRE

District	Year	No. of farms	Fertilizer treatment								General mean	Standard error
			None	N.	P.	K.	NP.	NK.	PK.	NPK.		
No. 1.—Red River Valley	1929	10	22.9	24.4	27.3	22.9	29.4	24.1	27.1	29.4	25.94	0.718
	1930	11	20.8	23.3	23.5	21.4	26.3	22.2	23.3	26.9	23.46	0.750
	1931	10	19.1	20.6	22.9	18.6	25.2	19.5	23.6	25.3	21.85	0.687
No. 2.—Assiniboine Delta	1929	9	21.4	25.2	26.2	23.0	30.2	22.4	26.7	29.6	25.59	1.01
	1930	11	21.7	24.6	22.9	21.3	26.5	24.3	23.4	28.2	24.11	0.913
	1931	8	13.3	13.0	14.5	13.1	14.2	12.5	14.2	14.9	13.71	0.650
No. 3.*—Riding Mountain Wash	1929	3	20.4	18.9	24.0	19.4	27.4	19.3	25.3	27.4	22.76	1.196
	1930	3	20.9	23.5	24.2	20.8	26.8	24.3	23.0	26.2	23.71	1.002
No. 4.—Dauphin Area	1929	4	15.0	15.8	19.0	14.2	22.4	15.3	19.8	22.9	18.05	0.826
	1930	3	19.0	22.1	24.2	19.8	27.3	20.7	24.8	29.4	23.41	1.091
	1931	2	22.5	25.2	24.6	25.0	28.6	28.9	26.7	28.5	26.25	0.904
No. 5.—Swan River Valley	1929	5	27.2	27.5	29.5	26.2	31.7	27.4	28.9	33.5	28.99	1.093
	1930	3	12.3	18.2	15.2	15.9	17.9	18.5	18.0	25.7	17.71	3.200
	1931	4	25.8	26.7	34.0	27.7	33.9	29.0	33.8	35.9	30.85	2.340
No. 6.—Northern Drift	1929	15	24.1	23.2	27.7	23.2	29.6	24.7	28.4	30.7	26.45	0.734
	1930	16	20.3	22.8	24.0	21.2	25.3	22.1	24.1	26.0	23.22	0.659
	1931	14	18.1	18.1	23.3	19.8	23.5	17.4	22.6	22.6	20.68	0.954
No. 7.—Central Drift	1929	11	22.7	22.0	25.0	21.4	26.0	21.2	26.0	26.8	23.89	0.711
	1930	8	20.9	20.8	26.3	21.6	27.7	21.0	26.2	26.9	23.92	0.868
	1931	7	10.6	12.9	13.8	12.5	13.3	12.6	14.1	13.1	12.86	1.071
No. 8.—Southern Drift	1929	13	14.8	15.7	17.1	14.1	19.0	15.7	17.0	18.4	16.48	0.627
	1930	20	20.2	21.7	24.1	20.2	23.8	20.8	23.5	24.8	22.39	0.773
	1931	10	8.1	8.9	10.2	7.7	9.6	8.5	10.1	10.2	9.16	1.602
No. 9.*—South Western Area	1929	22	19.6	19.5	22.6	19.7	23.5	18.8	22.9	22.8	21.18	0.506
	1930	26	16.7	17.0	19.9	16.8	20.8	17.1	19.2	20.2	18.46	0.400

*No comparable records in Districts 3 and 9 in 1931 on account of drought

TABLE 2.—RESULTS OF ANALYSIS OF VARIANCE OF YIELD

District	Year	Treatment mean squares							Error	
		Single elements			Interaction effects				Degrees of freedom	Mean square
		N.	P.	K.	NXP.	NXK.	PXK.	NXPXK.		
No. 1.—Red River Valley	1929	62.84†	445 10†	0 21	3 57	0 01	0 09	0 45	63	5.15
	1930	130 39†	204 84†	0 00	13 78	1 06	0 74	8 21	70	6.20
	1931	52.00†	462 24†	0 86	3 32	1 33	6 67	0 02	63	4.69
No. 2.—Assiniboine Delta	1929	116 03†	482 57†	2 00	16 24	33 89	0 98	12 34	56	9.14
	1930	281 89†	112 28†	2 58	7 52	2 25	11 84	1 76	70	9 21
	1931	0 02	32 35†	0 00	1 29	0 88	0 93	1 02	49	3 38
No. 3.—Riding Mountain Wash	1929	6 10	255 45†	0 22	19.62*	0 01	1 26	2 88	14	4.29
	1930	53 10†	43 04†	0 43	0 08	0 84	2 38	0 04	14	3.01
No. 4.—Dauphin Area	1929	35 28†	284 41†	0 00	10 81	0 00	3 12	0 20	21	2 73
	1930	51 54	216 18†	1 62	5 07	0 13	4 08	5.30	14	19 57
	1931	38 44†	11 56*	16 00*	0 20	0 20	4 20	2 90	7	1 63
No. 5.—Swan River Valley	1929	43 47*	145.54†	0 01	17 57	6 64	2 97	1 55	28	5 97
	1930	135 47	53 10	79 21	1 24	0 84	16.93	25 30	14	30 61
	1931	8 82	406 12†	17 40	0 03	3 25	3 25	1 63	21	21 84
No. 6.—Northern Drift	1929	42 13*	847 48†	11 72	24 57	14 49	2 67	7 44	98	8 80
	1930	88 48†	345 84†	2 22	0 01	2 12	0 81	9 73	105	6.94
	1931	7 93	612 89†	0 76	11 96	11 70	11 59	9 03	91	12 73
No. 7.—Central Drift	1929	1 05	371 46†	0 13	8 91	0 21	20 62	0 76	70	5 58
	1930	1 91	521 15†	0 00	7 68	1 64	3 59	0 03	49	6 02
	1931	0 64	28 29	2 74	13 80	7 14	1 86	2 84	42	8 03
No. 8.—Southern Drift	1929	54 96†	203 84†	3 62	0 65	0 06	0.02	2 39	84	5 11
	1930	24 81	36 23	0 57	2 29	1 10	4 34	15 60	133	11 95
	1931	1 77	60 03	0 04	4 66	0 50	1 95	0 67	63	25.65
No. 9.—South Western Area	1929	0 02	562 70†	2 53	10 55	8 86	0.01	0 08	148	5 66
	1930	21 08*	511 48†	4 82	5 61	0 01	6 74	0 00	175	4.16

*Indicates treatment mean square significantly greater than error, value of z between 5% and 1% point.
†Indicates treatment mean square significantly greater than error, value of z beyond 1% point.

TABLE 3.—EFFECT OF SINGLE ELEMENTS ON YIELD IN BUSHELS PER ACRE

District	Year	With N.	Without N.	Difference	With P.	Without P.	Difference	With K.	Without K.	Difference	Standard error of difference
No. 1.—Red River Valley	1929	26.8	25.1	1.7	28.3	23.6	4.7	25.9	26.0	−0.1	0.359
	1930	24.7	22.2	2.5	25.0	21.9	3.1	23.4	23.4	0.0	0.375
	1931	22.7	21.0	1.7	24.2	19.4	4.8	21.8	22.0	−0.2	0.343
No. 2.—Assiniboine Delta	1929	26.9	24.3	2.6	28.2	23.0	5.2	25.4	25.8	−0.4	0.500
	1930	25.9	22.3	3.6	25.2	23.0	2.2	24.3	23.9	0.4	0.456
	1931	13.8	13.8	0.0	14.5	13.1	1.4	13.8	13.8	0.0	0.325
No. 3.—Riding Mountain Wash	1929	23.3	22.3	1.0	26.0	19.5	6.5	22.9	22.7	0.2	0.598
	1930	25.2	22.2	3.0	25.0	22.4	2.6	23.6	23.8	−0.2	0.501
No 4 Dauphin Area	1929	19.1	17.0	2.1	21.0	15.1	5.9	18.1	18.1	0.0	0.413
	1930	24.9	22.0	2.9	26.4	20.4	6.0	23.7	23.2	0.5	0.545
	1931	27.8	24.7	3.1	27.1	25.4	1.7	27.3	25.3	2.0	0.452
No. 5.—Swan River Valley	1929	30.0	28.0	2.0	30.9	27.1	3.8	29.0	29.0	0.0	0.546
	1930	20.1	15.3	4.8	19.2	16.2	3.0	19.5	15.9	3.6	0.600
	1931	31.4	30.3	1.1	34.4	27.3	7.1	31.6	30.1	1.5	1.170
No. 6.—Northern Drift	1929	27.0	25.9	1.1	29.1	23.8	5.3	26.8	26.1	0.7	0.367
	1930	24.0	22.4	1.6	24.9	21.6	3.3	23.3	23.1	0.2	0.329
	1931	20.4	20.9	−0.5	23.0	18.3	4.7	20.6	20.7	−0.1	0.477
No. 7.—Central Drift	1929	24.0	23.8	0.2	25.9	21.8	4.1	23.9	23.9	0.0	0.355
	1930	24.1	23.8	0.3	26.8	21.1	5.7	23.9	23.9	0.0	0.434
	1931	13.0	12.8	0.2	13.6	12.2	1.4	13.1	12.7	0.4	0.535
No. 8.—Southern Drift	1929	17.2	15.8	1.4	17.9	15.1	2.8	16.3	16.7	−0.4	0.313
	1930	22.8	22.0	0.8	24.1	20.8	3.3	22.4	22.5	−0.1	0.386
	1931	9.3	9.0	0.3	10.0	8.3	1.7	9.1	9.2	−0.1	0.801
No. 9.—Southwestern Area	1929	24.5	24.5	0.0	26.6	22.4	4.2	24.4	24.7	−0.3	0.253
	1930	18.8	18.1	0.7	20.0	16.9	3.1	18.3	18.6	−0.3	0.200
No. 1.—Average all plots	29–31	24.72	22.76	1.96	25.82	21.66	4.16	23.69	23.79	−0.10	0.208
No. 2.—Average all plots	29–31	22.74	20.52	2.22	23.11	20.15	2.96	21.64	21.62	0.02	0.260
No. 3.—Average all plots	29–30	24.23	22.25	1.99	25.54	20.94	4.60	23.22	23.26	−0.04	0.390
No. 4.—Average all plots	29–31	22.97	20.38	2.59	24.19	19.16	5.03	21.98	21.37	0.61	0.476
No. 5.—Average all plots	29–31	28.00	25.59	2.41	29.15	24.44	4.71	27.50	26.09	1.41	0.590
No. 6.—Average all plots	29–31	23.91	23.09	0.82	25.70	21.30	4.40	23.63	23.37	0.26	0.228
No. 7.—Average all plots	29–31	21.07	20.81	0.26	22.88	19.00	3.88	20.98	20.90	0.08	0.247
No. 8.—Average all plots	29–31	17.98	17.11	0.87	18.94	16.15	2.79	17.46	17.63	−0.17	0.274
No. 9.—Average all plots	29–30	19.88	19.54	0.34	21.38	18.04	3.34	19.57	19.85	−0.28	0.159

the other hand, when two or more elements gave increase when applied singly, their combination invariably resulted in a greater increase than that secured from both elements singly.

TABLE 4.—SUMMARY OF FERTILIZER TRIALS WITH WHEAT IN MANITOBA ARRANGED (A) FROM SOUTH TO NORTH AND (B) FROM EAST TO WEST (3 YEAR AVERAGE, 1929-30-31)

A. Average increase in per cent by districts from south to north

District	Mean yield of checks per acre	Increase or decrease in per cent with: N	P_2O_5	K_2O	Standard error
	Bus.				
1	20 9	8 51	19 49	−0 50	0 878
2	18 8	8 24	14 46	−0 08	1 206
3*	20 6	8 78	22 19	−0 20	1 685
4	18 8	12 75	24 38	3 41	1 231
5	21 8	13 23	19 38	8 85	3 326

B Average increase in per cent by districts from east to west

District	Mean yield of checks per acre	Increase or decrease in per cent with: N	P_2O_5	K_2O	Standard error
	Bus				
Average of 1, 2 and 3		8 51	18 71	−0 26	
6	20 8	3 04	20 80	0 87	1.014
8	14 4	5 22	18 45	−1 16	3 038
7	18 1	1 40	19 04	1 00	1 594
9*	18 1	1 58	18 39	−1 33	0 807

*2 yrs. 1929-1930 only.

SUPPLEMENTARY TRIALS

As a result of the earlier trials, the use of ammonium phosphate 10–48 was recommended in districts 1, 2, 3, 4 and 6, and the practice of applying this fertilizer was adopted on a large number of farms with the same beneficial results as were secured in the three-year trials here reported. However, in the most northerly district (5, Swan River Valley) a number of farmers reported that the ammonium phosphate alone did not give the marked increase expected. Greenhouse experiments indicated that this was due to the fact that the ammonium phosphate 10–48 did not contain sufficient nitrogen in combination with the phosphate for this area. Consequently acre field trials were conducted on a number of farms in the Swan River Valley during the season of 1932. The field yields obtained are shown in Table 5.

TABLE 5.—FERTILIZER TRIALS IN THE SWAN RIVER VALLEY, 1932

Farm	Check	Yields of wheat in bushels per acre treated with: Triple super-phosphate	Ammonium phosphate	Ammonium phosphate and ammonium sulphate	Ammonium phosphate and potassium sulphate
1	35 0	49 9	54 6	60.1	55 4
2	31 1	32 4	36 2	44 7	45 7
3	28.7	37 7	33 1	39 1	40 3
Means	31 6	40 0	41 3	48 0	47.1
		Yields of oats in bushels per acre:			
4	62 8	95 5	106 6	103 0	102.2

The field and greenhouse trials supplementary to the three-year trials indicate therefore that mono-ammonium phosphate does not carry sufficient nitrogen along with the phosphate in this northern area, and that greater amounts of nitrogen should be applied with the phosphate similar to the quantities used in the three-year trials.

The conclusions from all the Swan River trials are that nitrogen is as important as phosphate in the northern belt, but that potash response is either seasonal or the result of local requirement only.

ZONATION AND FERTILIZER RECOMMENDATIONS

The field trials in the nine agricultural districts investigated and reported above, indicate three groups of districts according to fertilizer requirements when the drilling-in method is used (see Figure 4).

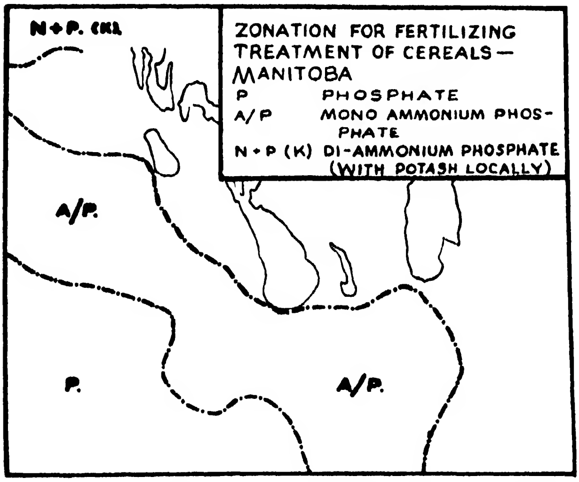

FIGURE 4. Zonation for fertilizer treatment of wheat indicated by the fertilizer trials.

(1) Significant response to phosphate only (districts 7, 8 and 9).

(2) Significant response to nitrogen and phosphate (districts 1, 2, 3, 4 and 6).

(3) Response to nitrogen and phosphate, with indications of local requirements of potash (district 5).

The geographical occurrence of these three groups of districts shows that their distribution is coincident with three major genetic soil belts, which occur as follows:—

A. Prairie soils.

Belt. 1. Normal chernozem, or southern belt.

Belt. 2. Northern chernozem, or intermediate belt.

B. Wooded area.

Belt. 3. Woodland invasion of northern chernozem and forest-soils, or northern belt.

1. ***Southern belt.*** The southern belt is located in the southwestern portion of the province and comprises agricultural districts 7, 8 and 9. The phytomorphic soils of this belt are typical chernozem or black-earth soil type; in the virgin condition they are prairie grass-land soils developed on drift or modified drift. Phosphate only gave significant response in the fertilizer experiments throughout this belt. Hence fertilizers of the triple superphosphate type should be recommended as the basic fertilizer for cereals in this zone.

2. ***Intermediate belt.*** Extending above the northern and eastern edge of the normal chernozem belt is a group of soil combinations which form a transitional belt between the normal black-earth soils and the wooded soils belt. In Manitoba, from east to west, these soil combinations include: (a) the black-earth and meadow-prairie soils on the deep lacustrine clays of Lake Agassiz; (b) The sandy chernozem-like soils of the Assiniboine Delta; (c) The northern chernozem (or northern black earth) soils on drift; and (d) Soils developed under woodland invasion on lacustrine sediments, modified drift and drift.

This intermediate belt includes agricultural districts 1, 2, 3, 4 and 6. Throughout this belt, which may be classed as the northern portion of the Manitoba prairies under aspen grove invasion as park land, phosphate gave the most significant increase in yield, but nitrogen in addition gave a smaller though significant response. Hence a fertilizer of the mono-ammonium phosphate type should be recommended as the basic fertilizer for the northern portion of the prairies.

Throughout the prairie region, namely in both the southern belt and the intermediate belt, there is no indication that potash for cereals is required generally.

3. ***The northern belt.*** Only one district of the grain growing area of the province (district 5) is included in this belt. The soils of this area were developed under forest or recent woodland invasion. The fertilizer trials to date in this area indicate: (a) that additional amounts of nitrogen are required with the phosphate than are required in the intermediate belt; (b) that a nitrogen and phosphate fertilizer of the di-ammonium phosphate type should be used as the basic combination throughout the district; and (c) that potash may be required in certain locations only.

NITRATE NITROGEN VS. AMMONIACAL NITROGEN

In the three-year fertilizer trials throughout the nine agricultural districts, two fertilizers were used as carriers of nitrogen where nitrogen was used alone, namely, ammonium sulphate and sodium nitrate. A comparison of the yields for these two fertilizer treatments for each of the nine districts in each of the three years shows an average increase of 1.31 bushels more when treated with ammonium sulphate than when treated with the sodium nitrate. This difference though small is highly significant. By grouping the average yield-increase of the nine districts into the three belts, the increases are shown to be progressive from south to north. In the southern belt (districts 7, 8 and 9) the increase from the ammonium sulphate treatment over the sodium nitrate treatments was .50 bushels. In the intermediate belt (districts 1, 2, 6, 3 and 4) the increase was 1.40 bushels. In the northern belt (district 5) the increase was 3.03 bushels. In general the sodium nitrate gave little or no response over the check, and in the dry seasons the nitrate tended to retard early growth and to depress slightly the yields in the southern belt.

WEATHER

The general weather conditions which prevailed during the three years the experiment was conducted are shown in Table 6. The average figures given are compiled from reports from the 25 meteorological stations located in the area investigated. The precipitation and temperature

figures for each of the three crop seasons of 1929, 1930 and 1931 were averaged for the stations in each district, and include the mean figures for the autumn months prior to the crop season (August to October) and for the growing months (April to July) only. The figures for the months in which the mean temperature was below freezing, namely, November to March, were not included, as the weather conditions of this period have little effect on the crop. The respective normal precipitation and temperature figures are presented in the same table for comparison. As a single expression value of precipitation and temperature a climatic factor was calculated similar to that used by McKibbin (4). The climatic factor here used is the total precipitation in inches for the seven months (fall and growing season) (P) divided by the respective difference between the mean monthly temperature and 32° F. (T) for the corresponding period. The higher values obtained by this method indicate relatively moist conditions, and inversely the lower values indicate drier conditions.

The figures in Table 6 indicate that the season of 1929, and to a greater extent the season 1931 were drier than the normal, while the season of 1930 approached the normal in precipitation, with higher than normal temperature. However, owing to the fact that the data for a number of the stations were incomplete, the mean figures can be used only to give a general idea of the conditions over the area as a whole. The stations are not sufficiently well distributed within each agricultural district, to justify the working out of correlations either with the district crop yields or the fertilizer increases by districts. The "climatic-factor" figures indicate however that during the three years of the experiment, the weather conditions were not the most favorable for crop production.

TABLE 6.—MEAN RAINFALL, TEMPERATURE, AND CALCULATED CLIMATIC FACTOR,* FOR THE PREVIOUS FALL MONTHS (AUGUST TO OCTOBER) AND THE GROWING SEASON (APRIL TO JULY) BY DISTRICTS, 1929, 1930 AND 1931

District	Precipitation P				Temperature T				Climatic factor P/T—32° F.			
	Normal	1929	1930	1931	Normal	1929	1930	1931	Normal	1929	1930	1931
		Inches				Degrees Fahrenheit						
1	14 89	8 43	13 73	9 50	53 3	53 0	55 6	55 4	70	40	58	41
2	14 15	7 08	14 68	9 27	53 6	53 0	55 4	55 2	65	34	63	40
3	—	—	—	—	—	—	—	—	—	—	—	—
4	13 33	—	8 77	7 31	51 4	53 0	55 8	55 3	69	—	37	31
5	—	—	—	—	—	—	—	—	—	—	—	—
6	13 33	8 16	13 38	8 09	51 6	49 4	52 2	52 4	68	47	66	.40
7	13 15	9 55	18 18	6 99	52 1	50 9	53 9	54 7	65	50	83	31
8	13 49	7 59	14 55	—	52 9	52 1	54 8	—	64	38	64	—
9	12 43	8 62	10 97	7 05	52 7	52 1	55 1	55 4	60	43	.47	30

*"Climatic-factor" here used = $\dfrac{\text{precipitation}}{\text{mean monthly temperature minus } 32^{\circ} \text{ F.}}$

POTENTIAL FERTILITY OF MANITOBA SOILS

A fundamental difference exists between the use of fertilizer to supply a deficiency to total nutrients in "deficient" soils, and in its use in the northern prairies to provide supplementary nutrients for crop stimulation during the critical early growth period. However, for purposes of com-

parison with other regions the potential fertility of the soils in the area covered is presented in summary form. The summary of the soil analyses here reported was compiled from a number of analyses of soils collected by Clevenger (*1*) from the areas subsequently covered by the fertilizer trials. The total nitrogen was determined by the Kjeldahl method and the phosphorus was determined by the fusion with magnesium nitrate method. All soil samples were taken to a depth of six and two-thirds inches. The 192 nitrogen determinations were made on cultivated soils. The 208 phosphorus determinations were made chiefly on cultivated soil, but include also 16 virgin samples, the phosphorus content of which was of similar values to those found in cultivated soils. These analyses were grouped by combining and averaging the percentage figures for the heavy to medium textured soils, and for the light textured soils in each of the three belts. The summaries are presented in Table 7.

The mean figures given in Table 7 lead to the conclusion that the soils of the area in which the fertilizer trials were conducted are of high average potential fertility, and that they are not commonly deficient in these two elements, with the possible exception of the lower values for phosphorus in the light textured soils of the southern belt. The figures compare very favorably with average regional figures from other areas. Hence the general response secured from the drilling-in of small quantities of phosphate in prairie soils, and of phosphate with the addition of nitrogen in the more northern portion of the prairies, is not due to the low values for total nutrients, but the increases appear to be related to climatic conditions, availability, and rate of intake. This phase of the problem requires treatment as a separate study.

TABLE 7. TOTAL NITROGEN AND TOTAL PHOSPHORUS IN MANITOBA SOILS

Agricultural District	Soil belt	Percentage total nitrogen and pounds per acre 6⅔ inches					
		Heavy to medium textured soils			Light textured soils		
		No of soil samples	Percentage of total nitrogen	Pounds per acre, 6⅔ inches	No of soil samples	Percentage of total nitrogen	Pounds per acre, 6⅔ inches
5	(3) Northern	20	494	9880	4	277	5540
1, 2, 3, 4, 6	(2) Intermediate	87	405	8100	29	302	6040
7, 8, 9	(1) Southern	34	360	7200	18	269	5380
Total		141			51		
		Percentage total phosphorus and pounds per acre 6⅔ inches					
5	(3) Northern	21	085	1700	4	089	1780
1, 2, 3, 4, 6	(2) Intermediate	102	082	1640	28	070	1400
7, 8, 9	(1) Southern	35	076	1520	18	061	1220
Total		158			50		

SUMMARY

1. Complete fertilizer trials with wheat, in which small quantities of eight different fertilizers were applied below the seed, were conducted throughout the grain growing area of Manitoba during 1929, 1930 and 1931. The area of the trials covered nine agricultural districts. The

records of the individual trials were compiled and the mean yields of the various treatments for each district obtained.

2. Three types of response were noted:

I. Significant and marked response to phosphate.

II. Significant and marked response to phosphate; and significant though smaller increase with nitrogen.

III. Significant response to both nitrogen and phosphate, with a local tendency for potash to give increased yields.

3. The response to nitrogen decreased from north to south, whereas phosphate gave response throughout. Potash gave no significant response in any of the prairie soils. Where increases were secured from nitrogen alone, ammonium sulphate proved superior to sodium nitrate.

4. The three types of response obtained coincide with three major soil belts, and hence the zonation for the fertilizer requirement of wheat in the northern prairie region is indicated, namely: (a) phosphate in the southern belt; (b) phosphate with small amounts of nitrogen in the northern portion of the northern prairies; and (c) nitrogen and phosphate in the wooded belt, with the addition of potash where required on local soils only.

5. The weather conditions which prevailed during the three seasons were shown to be less favorable than normal for crop production in two out of the three years.

6. The average total nitrogen and phosphate content of the soils of the area covered by the fertilizer trials is shown to be relatively high. Hence the trials were conducted on "potentially fertile" and not on "deficient" soils.

7. The introduction of the practice of drilling-in small quantities of fertilizer with the seed may be classed as one of the most important contributions to cereal production in Western Canada. In the majority of cases where the practice has been followed, marked increases in yield with other advantages have been obtained, even on soils famed for their high fertility. The reason for the general response of cereals to this method of fertilization under these conditions appears to be related to climatic conditions, availability of nutrients, and rate of intake, but the fundamental causes require investigation.

LITERATURE CITED

1. Clevenger, C. B. Unpublished Data, Chemistry Department, Manitoba Agricultural College, Winnipeg.
2. Dudley, F. L. Methods of applying fertilizers to wheat. Jour. Am. Soc. Agron., *22* : 6; 515 1930.
3. Fisher, R. A. and Wishart, J. The arrangement of field experiments and the statistical reduction of the results. Technical communication No. 10, Imperial Bureau of Soil Science, England. 1930.
4. McKibbin, R. R. Climate and soil leaching variations in Quebec. Sci. Agric., *13* : 7; 421. 1933.
5. Richardson, A. E. V. Wheat and its cultivation. Dept. of Agric., Australia, Bull No. 55.
6. Salter, R. M. et al. Recommendations of the joint fertilizer committee on fertilizer application. Journ. Am. Soc. Agron., *24* : 12; 998. 1932.
7. Truog, E. Annotated bibliography of works on methods of applying fertilizer. Report and Proceedings of Joint Committee on Fertilizer Application. Nat. Fert. Ass., Wash.. D.C., p. 43. 1928.

Résumé

Division en zones des prairies du nord au point de vue des engrais chimiques. J. H. Ellis, Service des sols, Département de l'Agronomie, Université du Manitoba.

Des essais d'engrais complets sur le blé, dans lesquels de petites quantités de huit espèces différentes d'engrais ont été appliquées par-dessous la semence, ont été conduits dans la région à grain du Manitoba en 1929, 1930 et 1931; ils couvraient au total neuf districts agricoles. Les notes prises sur les essais séparés ont été compilées et on a relevé les rendements moyens des différents traitements pour chaque district.

Trois genres d'action ont été notés: I. Action significative et marquée du phosphate; II. action significative et marquée du phosphate et significative, quoique plus faible, avec l'azote; III. action significative de l'azote et du phosphate, avec tendance locale pour la potasse à provoquer une augmentation de rendement.

L'action de l'azote diminuait en allant du nord au sud tandis que l'action du phosphate était prononcée partout. La potasse n'a exercé aucune action significative sur les sols des Prairies, quels qu'ils soient Là où l'azote était seul employé, le sulfate d'ammonium s'est montré supérieur au nitrate de soude. Les trois types d'action coincident avec les trois bandes principales de sol et c'est pourquoi la division en zones de la région du nord des prairies au point de vue des engrais nécessaires pour le blé est nettement indiquée, savoir. (a) phosphate dans la zone du sud; (b) phosphate avec de petites quantités d'azote dans la partie la plus au nord; et (c) azote et phosphate dans la zone boisée, avec l'addition de potasselorsque cela est nécessaire sur les sols locaux seulement. Les conditions de température qui ont régné pendant les trois saisons ont été moins favorables que la normale pour la production des récoltes dans deux années sur trois. On voit que la moyenne totale de la proportion d'azote et de phosphate dans les sols de la région couverte par les essais d'engrais chimiques est relativement élevée et que les essais ont été conduits sur les sols "potentiellement fertiles" et non pas sur des sols "dépourvus de fertilité". L'introduction de la pratique qui consiste à semer de petites quantités d'engrais avec la semence peut être classée comme l'une des contributions les plus importantes dans la production des céréales dans l'Ouest du Canada. Dans la majorité des cas où la pratique a été suivie, on a obtenu des augmentations sensibles de rendement ainsi que d'autres avantages, même sur des sols renommés pour leur haute fertilité. La raison de l'action exercée sur les céréales par ce mode de fertilisation dans ces conditions paraît être reliée aux conditions climatériques, à l'assimilabilité des principes fertilisants et au taux d'absorption, mais les causes fondamentales restent encore inconnues.

NUTRITIONAL STUDIES WITH CHRYSANTHEMUMS[1]

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MATERIALS AND METHODS

For several years chrysanthemums have been grown extensively in pots in the greenhouse at the Central Experimental Farm. From time to time many of the plants have been disfigured by foliage troubles, consisting of yellow streaking or mottling of the leaves, brown or reddish spotting and general lack of vigour. Experience derived from nutritional studies with other plants indicated that these troubles might be due to nutritional deficiences or lack of balance between nitrogen and the mineral elements. Plants were, therefore, grown in ground sand-stone in pots in the greenhouse and subjected to the following nutrient solutions. Each series consisted of five plants. The variety Sir William Clark was us

1. Normal solution
2. Normal solution + nitrogen
3. Normal solution + (nitrogen × 2)
4. Normal solution + (nitrogen × 3)
5. Normal solution − ½ nitrogen
6. Normal solution − ¼ nitrogen
7. Normal solution + (nitrogen + potassium)
8. Normal solution + (nitrogen + potassium) × 2
9. Normal solution + (nitrogen + potassium) × 3
10. ½ Normal solution
11. Normal solution + phosphorus
12. Normal solution + phosphorus + potassium
13. Normal solution + nitrogen + phosphorus
14. Normal solution + (nitrogen + phosphorus) × 2
15. Normal solution + (nitrogen + phosphorus) × 4
16. Normal solution lacking potassium
17. Normal solution lacking (phosphorus + ⅔ potassium)
18. Normal solution + potassium
19. Normal solution + (potassium × 2)
20. Normal solution + (potassium × 3).

Stock nutrient solutions

$MgSO_4.7H_2O$	140 gms. in 2000 cc. water
KH_2PO_4	70 gms. in 2000 cc. water
$CaCl_2$	150 gms. in 2000 cc. water
NH_4NO_3	360 gms. in 4000 cc. water
$MnSO_4$	1 gm. in 2000 cc. water
H_3BO_3	1 gm. in 1000 cc. water
KNO_3	50 gms. in 1000 cc. water
$NH_4H_2PO_4$	70 gms. in 2000 cc. water

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From these stock solutions the different solutions were made up as required. Below is given the amount of stock solutions made up to 5000 cc. to make a normal solution.

$MgSO_4.7H_2O$	70 cc.
KH_2PO_4	77 cc.
$CaCl_2$	74 cc.
NH_4NO_3	44.5 cc.
$MnSO_4$	5.3 cc.
H_3BO_3	28 cc.
Ferric chloride	10 cc. of 0 5% solution.

In solutions requiring excess of certain elements, additional potassium was added in the form of potassium nitrate, the nitrogen content being adjusted to agree with the normal. Additional phorphorus was added in the form of monoammonium phosphate, the nitrogen content being adjusted. In solutions lacking potassium, phosphorus was supplied in the form of monoammonium phosphate. In solutions lacking phosphorus, potassium was supplied in the form of potassium nitrate, the nitrogen content of the solution being adjusted. Solutions were fed twice a week at the rate of 200 cc. per pot.

In Table 1 are given the parts per million of the elements of the solutions fed.

TABLE I — PARTS PER MILLION OF ELEMENTS IN THE SOLUTIONS FED

Series	N	P	K	Mg	Ca.	S	Mn	B	Fe	Total
1	278	122 8	154 8	96 4	400	127	0 19	1 0	3 44	1185 24
2	556	122.8	154 8	96 4	400	127	19	1 0	3 44	1463 24
3	834	122 8	154 8	96 4	400	127	19	1 0	3 44	1741 24
4	1112	122 8	154 8	96 4	400	127	19	1 0	3 44	2019 24
5	139	122 8	154 8	96 4	400	127	19	1 0	3 44	1046.24
6	208	122 8	154 8	96 4	400	127	19	1 0	3 44	1115 24
7	556	122 8	309 6	96 4	400	127	19	1 0	3 44	1804 00
8	834	122 8	464 4	96 4	400	127	19	1 0	3 44	2050 84
9	1112	122 8	619 2	96 4	400	127	19	1 0	3 44	2483 64
10	139	61 4	77 4	48.2	200	63 5	19	1 0	3 44	5957 40
11	278	245 6	154 8	96 4	400	127	19	1 0	3 44	1308 04
12	278	245 6	309 6	96 4	400	127	19	1 0	3 44	1462 84
13	556	245 6	154 8	96 4	400	127	19	1 0	3 44	1586 04
14	834	368 4	154 8	96 4	400	127	19	1 0	3 44	1986 84
15	1390	614 0	154 8	96 4	400	127	19	1 0	3 44	2788 44
16	333 4	122 8	—	96 4	400	127	19	1 0	3 44	1085 84
17	297 4		51 8	96 4	400	127	19	1 0	3 44	978.84
18	278	122 8	309 6	96 4	400	127	19	1 0	3 44	1340 04
19	278	122 8	404 4	96 4	400	127	19	1 0	3 44	1494 84
20	278	122 8	619 2	96 4	400	127	19	1 0	3.44	1649 64

EXPERIMENTS WITH VARIETY SIR WILLIAM CLARK

Foliage and Growth Characteristics

Plants receiving the normal solution were fairly vigorous, with the foliage tending to be somewhat light green in colour and a few of the extreme bottom leaves drying and dying, this injury commencing as a marginal chlorosis, later involving large areas between the veins and eventually

FIGURE 1. Marginal chlorosis due to excess feeding of nitrogen.

FIGURE 2. More advanced stage of chlorosis due to excess feeding of nitrogen or a high nitrogen-potassium ratio.

causing burning and dying of the affected leaves (see Figures 1 and 2). As the nitrogen application was increased in Series 2, 3 and 4 the plants increased in vigour, the foliage became darker green in colour and the leaves larger in size. However, with the increase of nitrogen there was a corresponding increase of burning and dying of the leaves from the base of the plant up, until in Series 3 and 4 the foliage was burnt and dying for a foot to half way up the plant. The upper half of the plant was characterized by marked chlorosis gradually decreasing in severity so that the leaves at the top of the plant showed but slight marginal chlorosis. Series 5, receiving but half the normal amount of nitrogen, was lacking in vigour, with small leaves; the foliage was light green in colour, with the lower leaves yellowish with reddened veins. Series 6 was slightly more vigorous than Series 5, with slightly better coloured foliage. Where nitrogen and potassium were increased together, vigorous strong plants were obtained, with foliage of good dark green colour, burning of the foliage being restricted to a very few leaves at the base of the plant. All the plants in this group were better than those in the normal series, increasing in vigour and growth up to Series 9, which had the most vigorous growth and best coloured foliage of the experiment. Potassium had a marked effect in overcoming the burning and dying of the leaves on the lower part of the plant caused when nitrogen alone was increased, as in Series 3 and 4 (See Figures 3 and 4). The series receiving but half the normal solution was decidedly reduced in vigour; the foliage was light green with the lower

FIGURE 3. Browning and dying of the foliage from the base of the plant upwards, due to heavy feeding of nitrogen or nitrogen and phosphorus.

leaves pinkish red and spotted with red blotches. Adding an additional supply of phosphorus to the normal solution produced plants lacking in vigour, with burning and dying of the lower leaves and yellowish to reddish discolouration of the foliage (See Figure 3). Where phosphorus and potassium were increased together the growth tended to be spindly, foliage light green in colour, not equalling the normal solution. Increasing both the nitrogen and phosphorus together produced plants with similar injury to Series 3 and 4; where nitrogen alone was increased, the extent of the injury was somewhat more severe. The addition of phosphorus was not able to nullify the effect of excessive nitrogen but rather increased it. Lack of potassium was characterized by poor vigour, fading and yellow browning of the foliage, together with burning and dying of the foliage to within a short distance of the growing tips (See Figure 5). The burning and dying of the foliage from the base up was similar to that brought about by high nitrogen applications when potassium was not increased at

FIGURE 4. Foliage healthy to the base of the plant. Solution 3N+3K

the same time. The upper foliage was characterized by chlorotic areas similar to that caused by excess nitrogen feeding.

Lack of phosphorus was characterized by a great reduction in vigour, stunting and reddish-purpling of the leaves. The lower leaves that had died were reddish-purple in colour. The mottling was not a distinct chlorosis as in the case of excess nitrogen but rather a difference in the intensity of the basic green colour of the leaf. It did not commence at the margin as in the case of excess nitrogen feeding but occurred in irregular patches anywhere in the leaf.

Plants receiving additional potassium had somewhat light green foliage but good vigour, much better than the normal series. The lower leaves were faded to a yellow brown with slight yellow mottling.

A check series growing in soil had very good growth, but considerable burning and dying of the lower leaves, with yellow mottling higher up the plant.

In Table 2 are tabulated data regarding growth and bloom. Increased applications of nitrogen in Series 2, 3 and 4 caused a marked increase in the number of blossom buds, despite the burning and dying of the lower foliage, and had a tendency to delay the time of blooming. Reduction of nitrogen in the solution did not cause any reduction in the number of blossom buds, as compared with the normal, but retarded growth, as evidenced by a decrease in the height of the plants. Increasing nitrogen and potassium together in Series 7, 8 and 9 caused a much greater increase of blossom buds than when nitrogen alone was increased, Series 9 having

the greatest average number of blossom buds in the experiment. Vigour, as represented by height of plant, was also increased, along with the size of bloom. Increasing the phosphorus in the normal solution did not increase the number of blossom buds and had a retarding effect on the date of blooming. Increasing nitrogen and phosphorus together in Series 13, 14 and 15 caused a decrease of blossom buds as compared with increasing

FIGURE 5. Plant on left lacking potassium. Plant on right lacking phosphorus.

nitrogen alone. It also caused a decrease in vigour, a marked reduction in the size of bloom and a retarding effect on the date of blooming. Increased concentrations of potassium caused a decided increase in blossom bud production, good vigour and good size of bloom but not as great an increase as when nitrogen and potassium were increased together.

TABLE 2.—GROWTH AND BLOOM DATA

Series	Average height in inches	Average number of blossom buds per plant	Date of blooming	Average size of bloom, in.	Colour
1	54	62	Oct. 24	3 00	Orange to ochraceous orange.
2	54	82	Oct. 25	2 75	Orange to ochraceous orange.
3	51	109	Oct. 27	3 00	Empire yellow tinged with orange.
4	48	109	Oct. 27	2 50	Empire yellow tinged with orange.
5	46	65	Oct. 25	2 75	Orange to ochraceous orange.
6	48	68	Oct. 25	2 75	Orange to ochraceous orange.
7	54	116	Oct. 25	3 00	Orange to ochraceous orange
8	57	128	Oct. 22	3 25	Orange to ochraceous orange.
9	65	170	Oct. 23	3 25	Orange to ochraceous orange.
10	52	57	Oct. 28	2 50	Orange to ochraceous orange.
11	47	61	Oct. 27	2 75	Empire yellow tinged with orange.
12	48	83	Oct. 26	2 75	Orange to ochraceous orange.
13	45	78	Oct 25	2 50	Empire yellow tinged with orange.
14	46	86	Oct 28	2 25	Empire yellow tinged with orange
15	43	94	Oct. 28	2 00	Lemon chrome.
16	41	56 •	Oct. 29	2 00	Lemon chrome.
17	42	48	Oct 28	2 25	Ochraceous orange
18	52	97	Oct. 25	2 75	Orange to ochraceous orange.
19	56	97	Oct 25	3 00	Ochraceous orange.
20	57	129	Oct. 27	3 00	Ochraceous orange.
Soil	60	112	Oct 28	3 00	Ochraceous orange

Colour of Bloom

One of the most outstanding features of the experiment was the effect of the different nutrient solutions on the colour of the bloom, ranging from ochraceous orange to a lemon chrome (See Plate I).

Increasing the nitrogen from the normal solution brought about a gradual change from ochraceous orange to Empire yellow as the nitrogen concentrations increased. Decreasing the nitrogen from the normal caused a deepening of the orange colour as compared with the normal. Increasing the potassium with the nitrogen nullified the effect of high nitrogen concentration in producing yellow bloom. Increased phosphorus produced bloom ranging from Empire yellow to lemon chrome as the concentrations increased. Lack of potassium produced lemon chrome coloured bloom. Increased potassium over the normal produced the most highly coloured flowers, showing a gradual deepening of the orange colour as the potassium concentration increased (Plate I).

Chemical Ash Analysis

In analyzing the ash of plant material in this project, generally recognized methods from various sources were combined to give what seemed to be a satisfactory procedure. Table 3 gives the results from the analysis of the top ten inches of the plant in terms of ash constituents as percentage of ash.

The addition of nitrogen to the normal solution has resulted in a progressive decrease in K_2O accumulation in both ash and dry matter. There has been an almost corresponding increase in CaO in both ash and

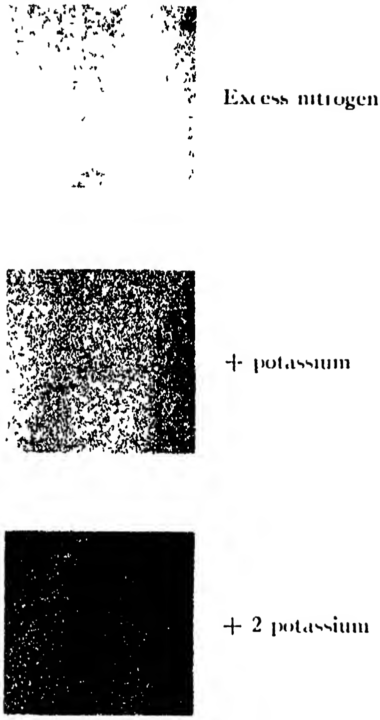

PLATE I

Bloom colour of Sir William Clark

dry matter with no definite trend in either MgO or P_2O_5 in ash but a slight increase in dry matter. Conversely the reduction of nitrogen in the normal solution has resulted in an increase in K_2O accumulation in both ash and dry matter, a slight decrease in CaO, and a very marked decrease in MgO, in both ash and dry matter with no definite trend in P_2O_5.

TABLE 3.—ASH CONSTITUENTS AS PERCENTAGE OF ASH FROM TOP TEN INCHES OF THE PLANT

Series	Treatment	Dry matter in fresh weight	Percent ash in dry matter	CaO	Ash constituents as % ash		
					MgO	K_2O	P_2O_5
1	Normal	19 5	5 93	23 74	13 26	22 36	16 97
2	+N	22 6	7 69	26 86	11 89	16 25	16 86
4	+ N × 3	23 4	6 65	29 46	13 39	13 11	18 15
5	− ½ N	13 0	7 08	21 67	8 94	29 69	14 89
6	− ¼ N	19 2	6 77	22 24	9 58	25 89	17 21
7	+(N + K)	15 8	9 17	21 78	9 66	25 13	13 51
8	+(N + K) × 2	18 1	7 94	22 18	8 35	27 97	12 45
9	+(N + K) × 3	21 7	6 90	21 37	7 85	30 76	9 46
10	½ Normal	13 6	6 90	26 50	11 26	19 22	15 01
11	+ P	21 5	10 30	24 65	10 28	20 50	25 59
12	+(P + K)	15 8	10 06	19 32	7 87	30 51	19 79
13	+(N + P)	19 1	8 08	24 01	11 12	18 88	27 80
14	+(N + P) × 2	22 1	8 38	25 73	11 01	13 70	35 49
15	+(N + P) × 4	23 6	7 54	26 10	9 71	14 86	44 11
16	− K	15 5	6 57	31 08	15 02	4 17	28 47
18	+ K	17 7	6 73	19 78	7 47	33 27	13 30
19	+ K × 2	22 0	6 87	17 01	5 07	40 69	11 53
20	+ K × 3	13 2	8 01	16 87	3 57	41 29	9 73

The addition of both nitrogen and potassium to the normal solution has brought about a progressive increase in K_2O in ash and dry matter; a slight reduction in CaO accumulation in ash; a very marked reduction of MgO in ash and dry matter and a marked reduction in P_2O_5 in both ash and dry matter. There is also a considerable increase of total ash in dry matter. Increased feeding of phosphorus has resulted in a marked increase of that element in both ash and dry matter; a decrease in the amount of K_2O in ash but not in dry matter; a decrease in the amount of MgO in ash but not in dry matter; a slight increase in CaO in ash but a large increase in dry matter. The large percentage of total ash in dry matter in this series probably accounts for the differences when worked on a dry weight basis as compared with the results when worked on a percentage of ash basis. It will be noted that when phosphorus is increased in the solution either alone or with nitrogen there is a marked increase of total ash in dry matter. Additional increments of potassium have also had this effect to a less degree. Increased feeding of phosphorus and nitrogen has resulted in a marked decrease of K_2O in ash; a considerable increase in CaO in ash and dry matter; a decrease of MgO in ash but an increase in dry matter and a very marked increase in P_2O_5 in both ash and dry matter.

The withdrawal of potassium from the normal solution has resulted in a very marked decrease in K_2O in both ash and dry matter; a marked increase in CaO in both ash and dry matter; a slight increase in MgO in

ash and dry matter and a very marked accumulation of P_2O_5 in ash and dry matter. Increased feeding of potassium has resulted in a marked increase of that element in ash and in dry matter; a considerable decrease in CaO accumulation in ash and in dry matter and a very marked decrease of MgO and P_2O_5 in ash and in dry matter.

Discussion

A consideration of the foregoing results brings out the following features.

TABLE 4.—ASH CONSTITUENTS AS PERCENTAGE OF DRY WEIGHT

Series	Dry weight	Per cent K_2O	Per cent CaO	Per cent MgO	Per cent P_2O_5
Normal	9 5	1 24	1 31	0 73	0 94
+ N	22 6	1 19	1 95	87	1 23
+ 3N	23 4	0 812	1 82	83	1 12
− ½ N	13 0	1 99	1 45	60	1 00
− ¼ N	19 2	1 66	1 43	61	1 10
+ (N + K)	15 8	2 12	1 90	84	1 18
+ (N + K) × 2	18 1	2 11	1 67	63	94
+ (N + K) × 3	21 7	2 02	1 40	51	62
½ Normal	13 6	1 24	1 71	73	97
+ P	21 5	1 95	2 41	1.00	2 50
+(P + K)	15 8	2 91	1 84	75	1 89
+(N + P)	19 1	1 61	2 06	95	2 38
+(N + P) × 2	22 1	1 09	2 04	87	2 81
+(N + P) × 4	23 6	1 06	1 87	69	3 15
− K	15 5	258	1 92	93	1 76
−(P + 2/3K)	17 9	827	2 04	94	1 19
+ K	17 7	2 06	1 22	47	82
+ K × 2	22 0	2 66	1 11	33	75
Top + K × 3	13 2	3 15	1 28	27	74
Middle	22 4	2 78	95	26	61
Bottom	28 6	2 33	.95	22	34

There is a marked negative correlation of the nitrogen-potassium ratio in the nutrient solution on the accumulation of certain elements in the plant. When the ratio of nitrogen to potassium is high, potassium accumulation is decreased and calcium accumulation is increased with slight increases in MgO and P_2O_5 in dry matter. When this ratio is low the potassium accumulation is increased and calcium and magnesium accumulation markedly decreased. A low nitrogen-potassium ratio has a very marked effect on limiting the MgO accumulation. The above conditions hold true whether the change in nitrogen potassium ratio is brought about by varying either the nitrogen or potassium in the nutrient solution. Varying the potassium concentration in the nutrient solution appears to have an influence also independent of the nitrogen potassium ratio. The addition of potassium causes a marked decrease in the accumulation of P_2O_5 in the plant and the withdrawal of potassium causes a marked increase in P_2O_5 accumulation in the plant. There appears to be a marked negative correlation between these two elements similar to that reported in (*1*). The addition of phosphorus to the normal solution causes a decreased accumulation of potassium and an increased accumulation of CaO in ash.

There are certain outstanding points from the ash analysis which correlate to a degree with the foliage conditions and appearance of the plants. Burning of the lower foliage, chlorotic streaking of the younger growth and lack of colour development in the bloom were found in series receiving additional increments of nitrogen, series in which the potassium was withdrawn and series receiving additional increments of phosphorus. An examination of the ash analyses data from these treatments reveal certain things in common. Thus, they are all lower in potassium and all higher in calcium than the normal. In addition the plus phosphorus and minus potassium series were much higher in P_2O_5. In these latter series the injury to the plants was more severe.

Plants devoid of these injurious symptoms were found in the minus nitrogen series, the plus potassium series and series in which both nitrogen and the potassium were increased in proportion. The ash analysis revealed these plants to be all higher in potassium all lower in calcium and all much lower in magnesium than the normal. The plants receiving additional increments of potassium were also much lower in phosphorus and it was in these series that the best plants were produced with the best coloured bloom.

These foliage troubles and lack of development of bloom colour may therefore be associated with low potassium in plant ash, high calcium magnesium or phosphorus, brought about by widening the nitrogen-potassium ratio in the nutrient solution and by increasing the concentration of phosphorus. The plants in the normal solution showed some signs of foliage injury and lack of bloom colour. This was corrected by narrowing down the nitrogen-potassium ratio as in series 18 and 19. In light of the ash analysis it would be interesting to see if a similar result might be secured by cutting down the calcium, magnesium or phosphorus concentration in the arbitrary normal solution.

REPETITION ON VARIETIES MARIE ADELAIDE AND MRS. F. C. ELFORD

Subsequently, it was considered advisable to determine whether other varieties would respond to similar treatments in a like manner. The varieties Marie Adelaide and Mrs. F. C. Elford were employed, repeating the following treatments:—

1. Normal solution + (nitrogen × 3)
2. Normal solution − ½ nitrogen
3. Normal solution + (N + K) × 3
4. Normal solution + phosphorus
5. Normal solution + (N + P) × 4
6. Normal solution lacking potassium
7. Normal solution lacking phosphorus
8. Normal solution + (potassium × 3).

Foliage and Growth Characteristics

In general, the behaviour of both these varieties was similar, so that the following remarks are to be construed as pertaining to the two varieties unless otherwise noted.

Plants receiving additional increments of nitrogen showed very good vigour with the foliage dark green and the leaves large in size. However,

after exposure to the treatment for some time, burning and drying of the lower leaves occurred with mottling and chlorosis of the upper foliage, the injury commencing at the base of the plant and progressing upward. The behaviour of these two varieties was identical with that of Sir William Clark in the former experiment. Series 2, receiving but half the normal amount of nitrogen was lacking in vigour, the foliage being light green in colour. However, there was no burning, mottling or chlorosis of the foliage as in the previous series.

Where nitrogen and potassium were increased together, vigorous plants, with healthy green foliage were produced. There was no burning or chlorosis of the foliage. The addition of potassium almost completely eliminated the foliage injury caused when nitrogen alone was increased. An additional increment of phosphorus to the normal solution produced plants reduced in vigour, with foliage light green in colour. There was considerable burning of the lower leaves commencing as a marginal scorch, reddish in colour.

Increasing the nitrogen and phosphorus together produced excessive burning of the leaves extending from the base half-way up the plant. The upper foliage of the plants was a dull dark green with a reddening of some of the leaves commencing on the under surface. This latter symptom is strongly reminiscent of potassium deficiency as exhibited in strawberries.

Lack of potassium was evidenced by weak spindly plants, leaves much reduced in size with severe burning of the foliage extending from the base two-thirds up the plant. The variety Mrs. Elford was affected the worse.

In the variety Mrs. Elford, the withdrawal of phosphorus from the nutrient solution produced weak spindly plants, with the lower leaves a dull reddish-purple. Later, these leaves died and became a dark brown, easily distinguished from the light brown dead leaves, produced from excessive feeding of nitrogen.

In the variety Marie Adelaide the withdrawal of phosphorus produced weak plants with the upper leaves a dull dark green, the lower leaves somewhat faded in colour and characterized by a red spotting. In a general way, the response of the three varieties to the nutritional treatments was similar, although there is some indication that response may be qualified in degree and character by variety. There is the possibility that in a finer sense it may be necessary to group varieties according to their nutritional requirements.

The addition of potassium to the normal solution produced strong vigorous plants with no chlorosis or burning of the foliage. The general colour of the foliage was somewhat light green.

In Table 5 are tabulated data regarding growth and bloom. Excessive feeding of nitrogen as in series one produced plants with a large number of blossom buds but had a tendency to delay the time of blooming. Reduction of nitrogen in the solution produced a much smaller number of blossom buds and also reduced growth as evidenced by the height. Increasing nitrogen and potassium together caused a much larger production of blossom buds than when nitrogen alone was increased. Vigour, as represented by height of plant, was also increased, along with the size of bloom. These plants were also somewhat earlier in coming into bloom. The

addition of nitrogen and phosphorus to the normal solution caused a very large decrease in blossom buds as compared with increasing the nitrogen alone in the variety Marie Adelaide, and a marked stunting of the plants, but in the variety Mrs. Elford the treatment did not have such a marked effect.

The withdrawal of potassium from the solution caused a marked reduction in the vigour, the number of blossom buds and the size of bloom. The withdrawal of phosphorus from the solution had a similar effect as the withdrawal of potassium in causing a stunting of the plants, a reduction of blossom buds and a reduction in the size of bloom. Additional increments of potassium caused an increase in blossom buds and in the size of bloom but the number of bloom was not as large as when nitrogen and potassium were increased together.

Table 5.—Growth and bloom data

Mrs. F. C. Elford

Series	Average height in inches	Average number of blossom buds per plant	Date of blooming	Average size of bloom	Colour
				in	
1	55	91	Oct. 23	3¼	Light pink.
2	48	54	Oct. 25	3	Slightly darker than No. 1.
3	62	172	Oct. 21	3½	Not quite as deep as No. 2.
4	47	72	Oct. 23	3	Light pink.
5	51	91	Oct. 19	3	Lighter than Ser. 1.
6	42	49	Oct. 22	2¾	Very pale, almost white.
7	39	24	Oct. 22	2¾	Deeper in color than No. 2.
8	50	97	Oct. 24	3	Deepest color of the series.
			Marie Adelaide		
1	47	95	Oct. 28	3	Orange.
2	44	53	Oct. 27	3	Ochraceous orange.
3	51	142	Oct. 23	3½	Orange to ochraceous orange.
4	40	66	Oct. 23	3	Light orange.
5	36	19	Oct. 27	3	Orange.
6	32	27	Oct. 25	2¾	Very light orange.
7	37	26	Oct. 26	2¾	Ochraceous orange.
8	46	103	Oct. 26	3½	Ochraceous orange.

Colour of Bloom

As in the variety Sir William Clark the fertilizer treatments had a considerable effect upon the production of depth of colour in the bloom.

In general, it may be said that increased feedings of nitrogen interfered with colour development, while increased feedings of potassium brought about the highest and richest bloom colour. Increased concentrations of phosphorus interfered with colour development while deficient phosphorus feeding increased the depth of colour.

Deficient potassium feeding was characterized by the greatest lack of colour development of the group. Development of bloom colour in Chrysanthemums is dependent on an adequate potassium supply. Not

only must the potassium be adequate in total amount but in its relative concentration to nitrogen and phosphorus. Thus excessive feeding of nitrogen or phosphorus will interfere with colour production even though a sufficient total amount of potassium is available if the ratio between the available potassium and these two elements is wide.

Chemical Data

Although no detailed ash analyses were made of plants from this experiment certain micro-chemical and colorimetric tests were made which to a certain extent bear out the analysis made on the former experiment. The results are tabled below:—

Series	Part of plant	Nitrate	Phosphorus	Potassium
1	Leaves	Low	Medium	
2	Leaves	Trace	Low	
3	Leaves	Very heavy	Medium	
4	Leaves	Negative	Medium	
5	Leaves	Negative	Medium	
6	Leaves	Negative	High	
7	Leaves	Medium	Low to medium	
8	Leaves	Medium	Medium	
1	Stems	High	Low	Heavy
2	Stems	Between low and medium	Low	Medium to heavy
3	Stems	Medium to high	Low	Extremely heavy
4	Stems	Trace	Medium	Medium
5	Stems	Trace	Medium to high	Medium
6	Stems	Medium to high	Medium	Fair to medium
7	Stems	Medium	Very low	Fair to medium
8	Stems	Low to medium	Low to medium	Very heavy

Increased nitrogen feeding as in Series I did not produce high nitrate-nitrogen in the leaves. This result might be expected from the colour of the foliage found in this series. However, the high nitrogen feeding was reflected in high nitrate-nitrogen in the stems. When both nitrogen and potassium feeding was high as in Series 3, nitrate-nitrogen was high in the leaves and medium in the stems. A narrow nitrogen potassium ratio in the nutrient solution appears necessary for an efficient translocation of the former element.

Additional increments of phosphorus in the nutrient solution gave negative to low results for nitrate-nitrogen in both leaves and stems.

Deficient potassium feeding gave negative nitrate-nitrogen results in the leaves and medium to high determination in the stems again showing the need of potassium in the translocation and metabolism of nitrogen. Deficient phosphorus feeding produced medium nitrate-nitrogen in both leaves and stems. In the detailed ash analysis it will be remembered that. low phosphorus feeding produced high potassium in plant ash.

Additional increments of potassium in the nutrient solution produced medium nitrate in both leaves and stem.

Heavy potassium feeding was reflected by high potassium in the stems of the plants. Additional increments of phosphorus in the solution somewhat reduced the amount of potassium in the plant stems. This is in

line with the ash analysis where it was shown that heavy phosphorus feeding depressed the amount of potassium in the ash. Deficient potassium feeding resulted in low potassium in the plant stems. Very slight differences were evident in the phosphate content of the leaves when estimated colorimetrically. In the stems high phosphorus feeding was reflected by higher phosphorus in the plant tissue. Deficient phosphorus feeding was reflected by low phosphorus in the plant stems. Deficient potassium feeding brought about somewhat higher phosphorus concentration in the stems. This is similar to the negative correlation between phosphorus and potassium found in the ash analysis.

EXPERIMENTS IN RIVER SAND

In addition to the foregoing experiments the varieties Marie Adelaide and Sir William Clark were grown in beds in river sand planted 10 inches by 10 inches and subjected to four different nutritional treatments.

It was considered that these conditions would more closely approximate commercial planting and demonstrate whether or not it would be feasible to use sand as a growing medium in a commercial way.

The four nutritional solutions employed were as follows:—

1. Normal solution + $(N + K) \times 3$
2. Normal solution + $K \times 3$
3. Normal solution + $N + 3K$
4. Normal solution + $K \times 2$.

All four treatments produced strong vigorous plants with bountiful bloom.

Series 1 was characterized by possessing the best foliage there being no mottling, chlorosis or burning. Series 2 was somewhat less vigorous with smaller leaves and the foliage somewhat lighter in colour. There was also a slight amount of mottling on the lower leaves. Series 3 and 4 were quite similar to series 1 in growth and vigour but the mottling on the lower leaves was somewhat more severe than in Series 2.

The intensity of bloom colour was correlated with a high potassium nitrogen ratio in the nutrient solution; that is the series ranked in the order 2, 3, 4, 1.

These results are similar to those found where plants were grown in ground sand-stone in pots and subjected to similar nutritional treatments. The high potassium feeding in Series 2, 3 and 4 although producing more highly coloured bloom did not produce as attractive foliage as in Series 1, the foliage was somewhat light green in colour and characterized by slight mottling of the lower leaves, as described previously in this paper. These plants compared quite favourably with plants grown in soil and handled in a commercial way. The foliage was devoid of the considerable scorching and chlorosis that marred the ornamental value of the plants growing in soil.

Summary

1. Three varieties of Chrysanthemums, Sir William Clark, Marie Adelaide, and Mrs. F. C. Elford, were grown in sandstone in pots and fed different nutrient solutions. The two former varieties were also grown in beds in river sand under nutritional treatments.

2. Definite foliage injuries were associated with a high nitrogen potassium ratio in the nutrient solution. Chrysanthemums are apparently high potassium feeders and a nitrogen-potassium ratio of 1 to 2 in the nutrient solution produced fine vigorous plants.

3. High phosphorus feeding in the presence of a high nitrogen potassium ratio increased the severity of foliage injuries.

4. Foliage symptoms were obtained for deficient phosphorus and deficient potassium treatments which should prove of value in diagnosis.

5. Yield data indicate the possibility of reduced flower bud formation and reduction in the size of bloom due to excess phosphorus feeding.

6. There is some indication that response to nutritional treatments may be qualified in degree and character by variety and it is suggested that it may be necessary to group varieties according to their nutritional requirements.

7. Fertilizer treatments had a marked effect upon the production of depth of colour in the bloom. Development of bloom colour in chrysanthemums is dependent on an adequate potassium supply, not only in total amount but in relation to the amount of nitrogen or phosphorus available.

8. Ash analysis of the plant top revealed the marked influence on the composition of ash and dry matter of the various treatments.

9. A negative correlation of the nitrogen-potassium ratio on the accumulation of potassium, calcium, magnesium and phosphorus in plant ash was revealed.

10. Antagonism between potassium and phosphorus was revealed, similar to that reported by the authors in studies on fragaria.

11. Foliage troubles and lack of development of bloom colour were associated with low potassium in plant ash, high calcium, magnesium or phosphorus, brought about by widening the nitrogen-potassium ratio in the nutrient solution or by increasing the concentration of phosphorus.

12. Microchemical and colorimetric tests of plant tissue gave the following results.

High nitrogen feeding was reflected in accumulation of high nitrate-nitrogen in the stems at the expense of the foliage. A narrow nitrogen-potassium ratio in the nutrient solution appears necessary for an efficient translocation of the former element.

Antagonism between potassium and phosphorus was revealed as in the ash analysis.

High potassium and high phosphorus feeding were reflected by a high test for these two elements in the plant tissue.

13. Plants grown in river sand and fed nutrient solutions compared quite favourably with plants grown in soil and handled in a commercial way.

REFERENCE

1. Davis, M. B., H. Hill, and F. B. Johnston. Nutritional studies with fragaria. II. A study of the effect of deficient and excess potassium, phosphorus, magnesium, calcium, and sulphur. Sci. Agr. *14* : 8; 411. 1934.

Résumé

Etudes de nutrition sur les chrysanthèmes. H. Hill, M. B. Davis et F. B. Johnston, Ferme expérimentale centrale, Ottawa, Canada.

Trois variétés de chrysanthèmes, "Sir William Clark", "Marie Adélaide" et "Mrs. F. C. Elford" ont été cultivées dans du grès en pots, où elles recevaient différentes solutions nutritives. Les deux premières ont aussi été cultivées en couche dans du sable de rivière, sous des traitements nutritifs différents. Les auteurs constatent qu'une proportion élevée d'azote-potassium dans la solution nutritive abîme le feuillage. Les chrysanthèmes paraissent exiger beaucoup de potassium, et une proportion relative d'azote-potassium de 1 à 2 dans la solution nutritive a produit de belles plantes vigoureuses, tandis qu'une forte quantité de phosphore jointe à une forte proportion relative d'azote-potassium, augmentait la gravité des avaries sur le feuillage. Les symptômes paraissant sur le feuillage sous les traitements déficitaires en phosphore et en potassium ont été notés et devraient servir à établir un diagnostic. Les données du rendement indiquent qu'il est possible qu'un excès de phosphore entraîne une réduction dans la formation de boutons à fruits ainsi que dans la grosseur des fleurs. Certains symptômes paraissent indiquer que l'action exercée par les traitements nutritifs varie en degré et en caractère suivant la variété et il est possible qu'il soit nécessaire de grouper les variétés, suivant leurs besoins nutritifs. Le traitement aux engrais chimiques a exercé un effet marqué sur la nuance de la couleur de la fleur. Le développement de la couleur de la fleur chez les chrysanthèmes est réglé par la quantité de potassium présente, non seulement par le montant total de potassium, mais aussi par la relation qui existe entre cette quantité de potassium et celle d'azote ou de phosphore assimilable. L'analyse des cendres de la tige de la plante a révélé l'effet sensible des différents traitements sur la composition de la cendre et de la matière sèche. Une corrélation négative de la relation azote-potassium sur l'accumulation de potassium, de calcium, de magnésium et de phosphore dans la cendre de la plante a été révélée. Un antagonisme entre le potassium et le phosphore a été noté, semblable à celui qui a été signalé par les auteurs dans leur travail sur le Fragaria. Les maladies du feuillage, le développement imparfait de la couleur de la fleur s'associent à la faible teneur en potassium dans la cendre de la plante, à la proportion élevée de calcium, de magnésium ou de phosphore, provoquée par l'élargissement de la relation azote-potassium dans la solution nutritive ou par l'augmentation de la concentration du phosphore. Des essais michrochimiques et colorimétriques du tissu de la plante ont donné les résultats suivants:—Une forte nutrition azotée a résulté en l'accumulation d'azote-nitrate dans les tiges, aux dépens du feuillage. Une relation étroite d'azote-potassium dans la solution nutritive paraît être nécessaire pour assurer une bonne translocation du premier élément. Un antagonisme entre le potassium et le phosphore a été révélé, de même que dans l'analyse de la cendre. Un apport considérable de potassium et de phosphore a provoqué un titre élevé de ces deux éléments dans le tissu de la plante. Les plantes cultivées dans le sable de rivière et qui recevaient des solutions nutritives soutenaient très avantageusement la comparaison avec les plantes cultivées dans de la terre et qui étaient traitées de la façon commerciale habituelle.

CONTROL OF THE NORTHERN FOWL MITE

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In view of the increase of the northern fowl mite *Liponyssus sylviarum* C. & F., experimental work was inaugurated at Macdonald College this year, the outline of which includes the control of the mite on the birds, on the perches and dropping boards and in the pens and houses. This work is incomplete, but as one phase has shown satisfactory results, it has been thought advisible to prepare this preliminary paper in order that others may avail themselves of the information.

A mixture of naphthalene flakes one part and vaseline two parts, has given 100% control on birds and on perches. The naphthalene should be thoroughly ground up in order to facilitate mixing and application, and then stirred into the vaseline. A small amount was applied around the tail and vent, as mites invariably congregate in this area; it was also applied to the perches, in which case none was placed on the birds. Repeated tests have been made, all of which have been correspondingly satisfactory.

Dichloricide and vaseline, in the same proportions, has also given satisfactory results. There are, however, two points in connection with its use which make it less desirable than naphthalene, namely, it costs more and tends to liquify the vaseline, which makes its application rather more difficult.

For some time, Black Leaf 40 (nicotine sulphate) has been used on perches in the control of the northern fowl mite, but comparative tests in the laboratory indicate that its action is slower than either that of naphthalene or dichloricide, and where a large area is to be covered, its cost is considerable.

It is of interest to note that naphthalene and vaseline has also been used against the body louse (*Eomenacanthus stramineus* Nitzsch) of the hen with good results. It acts rather more slowly on lice, and it should be applied to different parts of the bird. Lice do not, as a rule, show the same tendency to confine themselves to definite areas of a bird, as seems to be the habit in the case of the northern fowl mite, especially when the infestation is not severe. The fumes of naphthalene are apparently not as lethal to lice as they are to mites.

Résumé

Un mélange d'une partie d'écailles de naphtaline et de deux parties de vaseline a complètement supprimé la mite nordique des volailles (*Liponyssus sylvarium* C. & F.) sur les volailles et sur les juchoirs. Il est essentiel que la naphtaline soit parfaitement broyée afin d'en faciliter le mélange et l'application, puis ajoutée à la vaseline. Il en a été appliqué une petite quantité autour de la queue et de l'anus, car les mites se rassemblent invariablement dans cette région; on l'appliquait également aux juchoirs et dans ce cas on n'en mettait pas sur les oiseaux.

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THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

Indexes of business conditions in Canada continue to reflect a certain degree of stability. The index of wholesale prices was 72.3 in August as compared with 72.0 in July, the gain being entirely due to strength shown in the vegetable products group. Sub-indexes for other groups were either slightly lower or unchanged.

Retail Prices.—The index of retail prices, rents and costs of services rose fractionally fractionally from 78 4 in July to 78 7 in August. The chief factor in this increase was an advance in the prices of foods, the index rising from 68.4 to 69.3.

Physical Volume of Business.—The physical volume of business rose sharply in August when the index reached 99 0 as against 95 7 in July. The index of industrial production was 99 8 in August compared with 95 6 in July. In the mineral production group, consistent gains were registered and the index rose from 117.2 in July to 135.7 in August. Manufacturing showed a slight increase, the index rising from 99 0 to 100.7. Output of foodstuffs rose from 91 8 to 93 8. Tobacco releases advanced from 123 4 to 145 7. The forestry products indexes were also higher. Imports of crude petroleum advanced sharply. Indexes of construction and carloadings were also above those for July. The index of agricultural marketings rose from 148 8 to 172.8, due mainly to a larger movement of grains. Cold storage holdings were slightly above those in July.

Agricultural Products.—The index of wholesale prices of Canadian farm products advanced from 60 0 to 61 6. Prices of grains were considerably higher and this index rose from 57 8 to 60 7. This was the chief factor in the higher total index because the index of animal products declined fractionally from 63 7 in July to 63.1 in August. The position of wheat has improved materially during the past few months. Smaller European crops are reported as compared with those of 1933. The Bureau of Statistics has forecast a crop of 277,304,000 bushels in Canada as compared with an unrevised estimate of 269,729,000 bushels in 1933. Drought has reduced the United States crop to 493 million as compared with 528 million bushels in 1933, or about 60% of an average crop. It is anticipated that Canada may be called upon to supply half of the world demand for wheat which Mr. Broomhall recently estimated at 576 million bushels. The prospect, therefore, is for material reduction of surplus stocks in Canada before the end of the present crop year. Preliminary estimates indicate that the oat crop will be 344,746,000 bushels as compared with 307,478,000 bushels in 1933. Barley production is estimated at 68,000,000 bushels as against 63,359,000 last year and the rye crop is placed at 6,523,000 bushels whereas 4,327,000 bushels were grown in 1933. Average yields per acre have been slightly higher than in 1933 despite drought conditions in wide areas.

Exports of cattle during 1934 to September 20th were 38,928 head as compared with 36,676 in 1933. The number of cattle sold at public yards during the same periods numbered 447,552 this year as against 403,169 last year. Sales of calves were 270,578 and 234,689 head respectively. Hog marketings, on the other hand, were lower than in 1933. Total gradings were 2,132,917 for the first 38 weeks of 1934, whereas in 1933 during the same period 2,259,080 hogs were graded. Sales of sheep and lambs during 1934 have been 249,624 while 273,280 head were sold in 1933 at public yards.

Butter production for the seven months period ending July 31 was 135,540,736 pounds compared with 127,553,924 pounds during the seven months ending July 31, 1933. During the period December 4, 1933, to September 1, 1934, there were graded 658,963 boxes of cheese while in the period November 28, 1932, to September 2, 1933, gradings amounted to 763,659 boxes.

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1933									
Jan.	63.9	43.6	35.1	57.9	79.1	68.1	62.2	56.1	112.0
Feb.	63.6	43.0	36.0	54.7	78.4	67.0	60.0	76.5	127.6
Mar	64.4	44.7	38.0	56.0	77.8	68.4	62.5	129.0	135.8
April	65.4	46.8	41.1	56.4	78.0	69.8	65.1	104.1	112.7
May	66.9	51.2	46.9	58.4	77.0	76.4	72.7	95.4	110.4
June	67.6	52.6	49.4	57.9	77.0	82.2	79.8	221.9	119.9
July	70.5	60.1	60.8	59.0	77.2	84.1	82.6	221.9	119.9
Aug.	69.4	57.0	54.9	60.5	78.6	89.8	89.5	197.2	114.2
Sept.	68.9	54.7	49.5	63.4	78.8	90.8	90.2	101.1	115.7
Oct.	67.9	51.4	44.6	62.8	77.9	88.2	87.4	70.5	112.7
Nov.	68.7	53.8	46.7	65.8	78.1	85.5	83.9	41.8	111.1
Dec.	69.0	53.3	45.3	66.6	78.4	86.2	85.1	30.7	107.6
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	126.1
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	101.2
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.2	114.7

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1931, p. 15.
2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1931, p. 33, and Monthly Mimeographs 1933 and 1934.
3. Wholesale prices of grains, fruits and vegetables
4. Wholesale prices of Animals and Animal Products.
5. Including foods, rents, fuel, clothing and sundries. See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.
Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeographs 1933-1934.
6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

While improvement in prices of agricultural products may be noted, it is well to recognize that farm income is not evenly divided, because many farmers in drought areas have little to sell; on the whole, however, the immediate position of the farmer

is more reassuring than it was at this time a year ago. The continued improvement in industrial production gives hope for better returns from farming. Employment has, however, fallen off because of the layoff of workmen engaged in highway construction, and it must be remembered that sharp advances in prices without corresponding increase in consumers' purchasing power will result in reduction in consumption.

Reorganization in Great Britain.—The release of agricultural returns in England and Wales reveals among other things the fact that the acreage in wheat increased from 1,660,000 acres in 1933 to 1,759,000 in 1934. Acreage in sugar beets increased from 264,100 to 396,500. The number of cattle increased from 6,620,200 head to 6,659,000 and the number of pigs rose from 3,069,100 to 3,318,900. Acreage in orchard increased from 349,600 to 254,700 in 1934. Numbers of horses and sheep were lower. The area in hops, which are now under a marketing scheme, increased 900 acres this year as compared with 1933. These changes are quite significant of what is taking place in agricultural reorganization in England and Wales. Recent press reports indicate that a fruit marketing scheme is now being prepared. Conferences have been held with the fruit traders, representatives of the Jam Section of the Food Manufacturers' Federation and the canners' representatives. This scheme, like many others, is being sponsored by the National Farmers' Union and if it is decided to proceed with the plan, it is not expected that it will come into effect before the 1936 season. With the completion of a fruit marketing scheme, regulation of the marketing of most of the chief agricultural products of Great Britain will have been provided.

LA SITUATION ÉCONOMIQUE

PRÉPARÉE PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE DU MINISTÈRE DE L'AGRICULTURE À OTTAWA, D'APRÈS DES DONNÉES BASIQUES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

Les indices du commerce au Canada continuent à révéler un certain degré de stabilité. L'indice des prix de gros était de 72.3 en août contre 72.0 en juillet; l'augmentation est due presque entièrement à la fermeté présentée par le groupe des produits de légumes. Les sous-indices des autres groupes étaient un peu plus bas ou n'accusaient aucun changement.

Prix de détail.—L'indice des prix du détail, des loyers et des frais de services, s'est élevé de 78.4 en juillet à 78.7 en août. Le facteur principal de cette augmentation est la hausse qui s'est produite dans les prix des denrées alimentaires, dont l'indice a passé de 68.4 à 69.3.

Volume physique de la production.—Le volume physique de la production s'est élevé sensiblement en août, atteignant 99.0 contre 95.7 en juillet. L'indice de la production industrielle était de 99.8 en août contre 95 6 en juillet. Dans le groupe de la production minérale, des gains constants ont été enregistrés; l'indice s'est élevé de 117.2 en juillet à 135.7 en août. Les industries manufacturières révèlent une légère augmentation, de 99.0 à 100.7. La production des denrées alimentaires s'est élevée de 91 8 à 93 8. Les expéditions de tabac ont passé de 123.4 à 145.7. Les indices des produits des forêts étaient aussi plus élevés. Les importations de pétrole brut ont sensiblement augmenté. Les indices de l'industrie du bâtiment et des chargements de wagon étaient aussi supérieurs à ceux de juillet. L'indice des ventes agricoles s'est élevé de 148 8 à 172 8, principalement à cause des expéditions plus fortes de grains. La quantité de produits entreposés au froid était un peu plus forte qu'en juillet.

Produits agricoles.—L'indice des prix de gros des produits agricoles canadiens est passé de 60 0 à 61.6. Les prix des grains étaient beaucoup plus élevés; l'indice qui les dénote est passé de 57.8 à 60.7. C'était même là le facteur principal dans le relèvement de l'indice total, parce que l'indice des produits animaux a baissé d'une fraction, de 63.7 en juillet à 63 1 en août. La situation du blé s'est beaucoup améliorée en ces quelques derniers mois. Les récoltes européennes sont inférieures à celles de 1933.

Le Bureau de la Statistique prévoit une récolte de 277,304,000 boisseaux au Canada contre une évaluation non revisée de 269,729,000 boisseaux en 1933. Aux Etats-Unis, la récolte a été réduite à 493 millions par la sécheresse contre 528 millions de boisseaux en 1933, soit 60 pour cent environ d'une récolte moyenne. On prévoit que le Canada sera appelé à fournir la moitié de la demande mondiale de blé que M. Broomhall a évaluée récemment à 576 millions de boisseaux. Une réduction sensible des stocks de surplus au Canada avant la fin de l'année actuelle de récolte est donc à prévoir. Les évaluations préliminaires indiquent que la récolte d'avoine sera de 344,746,000 boisseaux contre 307,478,000 boisseaux en 1933. La production d'orge est évaluée à 68,000,000 de boisseaux contre 63,359,000 l'année dernière et la récolte de seigle à 6,523,000 boisseaux contre 4,327,000 en 1933. Les rendements moyens par acre ont été un peu plus élevés qu'en 1933 malgré la sécheresse qui a sévi dans de grandes étendues.

En 1934, à venir jusqu'au 20 septembre, les exportations de bestiaux ont été de 38,928 têtes contre 36,676 en 1933. Le nombre de bovins adultes vendus aux parcs publics pendant les mêmes périodes de temps a été de 447,552 cette année contre 403,169 l'année dernière. Celui des veaux a été de 270,578 contre 234,689 l'année dernière. Par contre, les ventes des porcs ont été plus faibles qu'en 1933. Le total des porcs classés a été de 2,132,917 pendant les 38 premières semaines de 1934 tandis

qu'il avait été de 2,259,080 pendant la même période en 1933. Les ventes de moutons et d'agneaux en 1934 ont été de 249,624; elles avaient été de 273,280 en 1933 aux marchés publics.

La production de beurre pendant les sept premiers mois qui ont pris fin au 31 juillet a été de 135,540,736 livres contre 127,553,924 livres pendant les sept mois finissant au 31 juillet 1933. Pendant la période allant du 4 décembre 1933 au 1er septembre 1934, il s'est classé 658,963 fromages tandis que pendant la période allant du 28 novembre 1932 au 2 septembre 1933 la quantité classée avait été de 763,659.

Tout en reconnaissant l'amélioration qui s'est produite dans les prix des produits agricoles, il faut admettre que le revenu de la ferme n'est pas également réparti parce qu'un grand nombre de cultivateurs dans les régions où la sécheresse a sévi n'ont pas grand'chose à vendre. Cependant, tout considéré, la situation immédiate des cultivateurs est plus rassurante qu'elle n'était à cette époque l'année dernière. L'amélioration soutenue de la production industrielle donne l'espoir d'une augmentation dans le revenu de l'agriculture. Il y a eu diminution dans l'embauchage, cependant, parce que beaucoup d'hommes qui étaient occupés à la construction des chemins ont été congédiés et il ne faut pas oublier que les hausses de prix qui ne sont pas accompagnées d'une augmentation correspondante dans le pouvoir d'achat des consommateurs ne peuvent qu'abaisser la consommation

La publication des rapports agricoles en Angleterre et dans le Pays de Galles révèle entre autres choses le fait que les emblavures de blé ont passé de 1,660,000 acres en 1933 à 1,759,000 acres en 1934. L'étendue plantée en betteraves à sucre est passée de 264,100 à 396,500. Le nombre de bovins, qui était de 6,620,200 est passé à 6,659,000 et le nombre de porcs s'est élevé de 3,069,100 à 3,318,900. L'étendue en vergers a augmenté de 249,600 à 254,700 en 1934. Il y a eu diminution dans le nombre des chevaux et des moutons. L'étendue en houblon, dont la vente est maintenant réglementée a augmenté de 900 acres cette année. Ces changements sont très significatifs de la réorganisation agricole qui a eu lieu en Angleterre et dans le Pays de Galles. Les rapports récents de la presse indiquent qu'on prépare actuellement un plan d'organisation du marché aux fruits. Il s'est tenu des conférences avec les marchands de fruits, les représentants de la section des confitures de la Fédération des Fabricants de Denrées Alimentaires et les représentants des conserveries. Ce plan, comme beaucoup d'autres, est lancé par l'Union Nationale des Cultivateurs (National Farmers' Union) et si l'on se décide à l'adopter, on ne prévoit pas qu'il entrera en vigueur avant la saison de 1936. Lorsque l'organisation du marché des fruits aura été complétée, presque tous les principaux produits agricoles de la Grande-Bretagne se trouveront sous un système de contrôle des ventes.

BOOK REVIEWS

LIPPINCOTT AND CARD. Poultry Production Lea & Febiger, Washington Square, Philadelphia, Pa. Fifth Edition.

Dr. L. E. Card, the co-author of "Poultry Production" by the late Dr. W. A. Lippincott, has brought forward an extremely valuable text for all interested in the science and practice of poultry culture. The revision of text material has been ably carried out, adding to the original material carefully selected new data and thought to make the present volume of utmost value to the student and the producer of poultry on the farm, as well as the handler of poultry products in commerce. Dr. Card has made an attempt to evaluate the newer knowledge of production and marketing in such a way as to give the reader a clearer understanding of the new reference material, as well as the basic principles laid down.

It has not been the attempt of the author to completely revise the entire text at one time, but undoubtedly as time progresses this text will prove to be a very valuable part of our poultry literature. A general revision of the text has, however, been made and additional chapters dealing with new phases of the subject have been added.

The list of references, arranged according to chapter subject, places before the reader an immediate source of reference material which will be greatly appreciated by students of the subject. —W. A. Maw.

J. C. ARTHUR. Manual of the rusts in United States and Canada. Illustrated by G. B. Cummins. *XV* + 438 pages, 1 map. Purdue Research Foundation, Lafayette, Indiana, 1934.

More than fifty years ago Dr. Arthur published his first paper on the rusts. For many years thereafter his time was largely occupied with other important matters; but he never forsook the rusts. Thanks largely to his efforts, the rusts of the United States and Canada are now usually easily identified. He has rendered a great service to everyone interested in the rusts by producing this manual. He has compressed into 438 pages the information requisite to the identification of our rusts; has summarized under each species the data regarding cultures or other noteworthy points; has listed the varieties and correlations of the species, the important synonym, and the ranges. A very conservative nomenclature is followed. Excellent illustrations by George B. Cummins add greatly to the value of the book. The preface explains the essentials of life history, relationships, and nomenclature of rusts, and is followed by a list of authors of species and a short glossary. The book concludes with a host index and a rust index. This work is a monument to the achievements of Dr. Arthur in elucidating the rusts of this continent. —G. R. Bisby.

GILBERT H. COLLINGS. Commercial Fertilizers. Philadelphia, Blakiston's Son & Co. 356 pages, illus. 1934.

This book is designed as a text on commercial fertilizers for students in Agricultural Colleges. The following points are emphasized; nature of raw materials, manufacturing processes, characteristics of finished products and the use of fertilizers. Four chapters are devoted to the nitrogen carrying fertilizers, three to the phosphates, three to the potash fertilizers and one to the fertilizers carrying other elements. As a text book it is sufficiently brief, well arranged and well edited. It should be of service as a guide to the district agent, the practical farmer, and the fertilizer industry. —F. A. Wyatt

SCIENTIFIC AGRICULTURE

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A NATIONAL CATTLE POLICY[1]

E. S. Archibald[2]

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The Executive of the Eastern Section of the Canadian Society of Animal Production asked me to open a discussion on this subject and I accepted with reluctance. The hesitation was based not on lack of interest in or a realization of the importance of the problem, but rather that the subject embraces so many governmental and professional activities that an enormous amount of study would be necessary, much more in fact than my time would permit.

The following analysis of the different aspects of this problem, with comments and suggestions, must then be considered at this time as a basis for a discussion rather than mature recommendations of any group of technical agriculturists.

In order to get a most intimate picture of existing and needed changes in our cattle practices in all parts of Canada, I have not hesitated to ask for information and other assistance from Federal and Provincial Live Stock Commissioners, the Dominion Bureau of Statistics at Ottawa, the heads of our Animal Husbandry Divisions at Agricultural Colleges, and others. Had time permitted I should like to have also gone much farther afield and obtained the criticisms and opinions of men in commercial aspects of the beef and dairy cattle industries of Canada. If, however, this subject is worth pursuing by our Society this is work which might well be undertaken by an organized committee both of the Eastern and Western sections.

I beg to acknowledge with thanks the prompt and hearty assistance which I had from those with whom I corresponded.

In approaching this subject one might well ask the question, "Is it possible to have a National Cattle Policy which will embrace the many aspects of our cattle industry?"

We already have many policies dealing with the live stock situation in Canada, at least some of which are as follows:—

1. Federal Bull Loaning Policy.
2. Federal Advanced Registry for Pure Bred Dairy Bulls.
3. Canadian Record of Performance for Pure Bred Dairy Cattle.
4. Federal Beef Grading Policy.
5. Federal Transportation Policy with a view of assisting farmers in Western Canada to establish themselves in the breeding of cattle.
6. Federal and Provincial Calf Club Policy.
7. Federal and Provincial Joint Bull Policies.

[1]Paper presented at the meeting of the Canadian Society of Animal Production—Eastern Section, Macdonald College, P.Q., June 26, 1934.
[2]Director, Experimental Farms, Dominion Department of Agriculture.

In addition, too, many of the Provinces have certain live stock policies such as Cow Testing and Bull Purchasing Policies.

Again, in connection with the health of our cattle, Federal and Provincial Departments of Agriculture are heavily involved in tuberculosis eradication policies, including Accredited Herds, T.B. Free Areas, and the like.

How then would it be possible to embody these and other aspects of our cattle industry into one policy? Frankly I doubt the wisdom of even attempting anything along these lines.

The danger of still further multiplying our numbers of policies is perhaps greater than we realize. I often wonder what would be the reaction of the average, or even our leading, live stock farmers, if we were to ask them to enumerate those policies now existing under Federal and Provincial regime within their provinces.

Not infrequently also we hear from taxpayers complaints regarding too much paternalism and government leadership to our farmers in matters in which the farmer himself should in co-operative effort assume the full responsibility and cost. Obviously such criticisms are made by people who have not the broadest knowledge of our industry and the needs for rapid improvement if Canadian live stock might continue to compete with the live stock of other countries. The farmer is not in a position to conduct research in any phase of our live stock industry. Moreover, public health so closely associated with animal health must of necessaity be protected with public funds. Farmers individually and collectively are not in a position to establish grading and branding systems as a guarantee to either domestic or export markets as to the healthfulness or the relative value of animal products.

Co-operation amongst farmers has been actively preached from one coast to the other over a long period of years, yet it seems so difficult to establish a background of co-operative philosophy in our scattered and heterogeneous population. Many excellent farmers in all parts of Canada are responsible for practices in production which result in a low grade product which is detrimental to the whole industry both on domestic and export markets. In other words, the average farmer probably knows much better than he practices. Whether it is possible to accomplish in Canada by acts, law, or other policies, what Denmark with her small country and homogeneous population has been able to do co-operatively is quite another matter.

Hence, in attempting to analyze this topic, I should like to voice my personal opinion that whatever changes of existing policies may be made in numbers or effectiveness, or whatever new policies may be evolved by governments, associations, co-operatives, or others, that the importance of educating the farmer as to his responsibility toward the whole industry be kept uppermost. In any such educational effort to a greater degree than in the past, the live stock producer of this country should be induced to lean less and less on the taxpayer for subsidies, compensations, grants, and the like.

Equally it is my candid opinion that in the problems of costs in organized marketing, particularly in relationship to our export trade, and in protection of human health against animal diseases, and in protection to the

Canadian live stock industry as a whole against the introduction of foreign diseases, the taxpayers of Canada must carry the load to a degree possibly greater than ever before.

I should like to discuss some of the major problems of our live stock industry in the order of importance in which they appear to me, not with the idea of welding these into a single policy or the creation of a new policy, but rather with the hope that suggestions may be forthcoming whereby existing policies and organizations may more effectively aid in bringing a degree of prosperity and permanency to our live stock industry which is not apparent at the present time.

FEEDS AND FEEDING

In my opinion better feeding systems are basic to all our live stock policies and developments. I have often wondered how much greater progress might have been made in cow testing work throughout Canada if we had first induced the farmer to so improve his crop practices of pasture and winter crops that he would have had more abundant and more nutritious feeds.

In the many years of assistance which have been given to farmers throughout Canada in the purchasing of pure bred live stock, including bulls, how much money has been wasted because of inadequate knowledge or poor practices in crop production? Would part of that money not have been much better spent in aiding the farmers to provide better feed supplies?

Governments past and present and their Departments of Agriculture have been instrumental in encouraging the opening up of lands which later were found unsuitable for crop production, and then have frantically looked around for some class of live stock which might aid the farmer to make a living. The same departments have in the past been responsible for developing dairy centres in the heart of the beef cattle country and have been parties to allowing and aiding the introduction of breeds of cattle through bull policies and the like into districts where the utmost harm was done through the mixing of types and breeds of live stock. Would not some of this money have been better employed in improving forages and pastures?

Live stock unions and other farmers' organizations in areas where the purchase of grain and mill feeds is advantageous and profitable at least have been instrumental on many occasions in placing before railways and railway commissions the significance of freight rates in order to provide cheaper feeds.

Infrequently departmental officers in agriculture, Federal and Provincial, have been called in for consultation, but there has been no concerted effort on the part of departmental officials in agriculture from one coast to the other to thoroughly review this situation and clearly define those areas in which the live stock industry must be dependent on imported concentrates.

Again as to feeding practices even in those districts where there is a reasonable security in crop production, such as we find here in Ontario and Quebec, the intelligent feeding of beef and dairy cattle has progressed very slowly during the past thirty years. *Balanced rations* have been advocated and described in detail at farmers' meetings in these provinces for fifty

years, yet as one visits the practical farmer or even sees his live stock in the fields, one wonders if our balanced rations are incorrect, our educational methods inadequate, or if the farmer through utter indifference finds it about as profitable to indifferently feed his live stock.

The greatest hope in this connection is found during recent years in the formation of Feeding Standards Boards. The province of Quebec, taking the leadership in this matter in the formation of a board consisting largely of technical men, has done more to systematically bring scientific and practical truths into the form of simple suggestions which any farmer may follow than had ever before been accomplished.

The province of Ontario with its Feed Committee, the Maritime Feed Board, and more recently the British Columbia Feed Board, have all come into existence with this same objective. The published results and recommendations for feeding resulting from the activities of some of these Boards are on our files and need no further comment. Resulting from their work, a much more careful economic survey of existing forage conditions, grain producing conditions, and grain imports, should be made.

The very active consideration of this problem of feeds and feeding by the Maritime Board is most encouraging. In analyzing their feeding policies they emphasize that more and better home-grown feeds are essential. This includes clear cut recommendations toward improving pastures, increasing and improving the quality of hay, increasing root production and the production of more home-grown grains with shorter rotations. These emphasize the necessity for continued and more active effort in inducing better feeding practices by clearly specifying variety of feeds, minerals in the ration, improvement of nutritive values and general education in the appreciation and uses of feeds.

Conditions in Ontario and Quebec are not at all dissimilar in this regard. The carrying power of pastures and the lower nutrition of pastures are probably the greatest limiting factors in our animal production work both as to volume and economy of production.

Poor pastures in these five provinces have done more to neutralize all our animal production policies than any other single factor.

Western Canada, although with different soil and climate, also is limited in any production policy by feeds and feeding practices. Manitoba, which more closely resembles Ontario than other Western provinces, according to our best authorities needs enormous improvements in pasture and forages as a basis for improved live stock production. Phosphate deficiency in the grass areas appears to be more marked than ever before. More legumes are needed. Minerals are needed in the feed mixtures and farmers must be taught to feed grain liberally, while at the same time building feed surpluses against those apparently inevitable drought years. An active Feed Board or Council in this province is beginning to effectively tackle this problem.

Saskatchewan and Alberta, because of climatic conditions, have a more complex problem. The Southern and Central parts of these provinces are our greatest grain-producing areas. Because of the limiting factor of precipitation, difficulties in obtaining stands of forage crops, and the inadequate water supply for live stock, mixed farming in many of these areas including a heavy cattle population is entirely out of the question.

I would refer to the very excellent analysis of this situation made by Dean Shaw at the World's Grain Conference at Regina in 1933 and the Live Stock Meetings at Moose Jaw in 1934.

North of these grain producing areas is natural mixed farming country and fortunately with a population of farmers who are liberal feeders. Improvements in feeding methods are no doubt advisable and must be worked out but this should be relatively simple.

Climate and soil types have determined that part of the southern part of Saskatchewan and Alberta and the Foot Hill country shall be a ranching country. Had this been fully realized thirty years ago the live stock industry of today would have been in better condition, while the settlers would have been saved a life-time of grief and disappointment. How to bring back this country to a high state of productivity from the ranching standpoint, how to renew the carrying power of the open ranges so that production costs may be reduced, how to supplement feed shortages both winter and summer on the more favoured soils, are vital problems on which the future of cattle ranching in Western Canada depends. No factor other than the present low prices of grass cattle from the range is of greater importance to the beef industry of Canada at the present time.

Another very interesting factor in the feeding of range cattle is the continuous demand for grain finished beef. Often one wonders if this propaganda is not carried farther than the Canadian consumer is prepared to pay or the export market is prepared to compensate. The worst of it is that in recent years those who, even under very sound guidance and supervision in feeding, have grain-finished range cattle under contract are worse off financially than they were previously. I will touch this matter again under the problem of marketing.

British Columbia interior valleys contain probably 160,000,000 acres of land suitable for grazing and crop production which is as yet undeveloped. Yet, those grazing areas now used are over-stocked and the range problem is as vital if not more so than that existing in Southern Alberta. Many points in these valleys which formerly had a good reputation of high class well finished grass cattle, according to shipping records at the present time are earning a most unenviable reputation in shipping poor cattle. This has been essentially a feed problem, yet its connection with marketing is obvious. The coastal areas which have developed dairying to an intense degree have less of a feeding problem than other parts of that province excepting in so far as the high cost of grains due in no small degree to transportation costs make the use of concentrates in dairy cattle production unduly expensive.

FREIGHT RATES

In the time at my disposal it would be unwise for me to elaborate this subject. One cannot but give fair consideration to the financial problems of the railway companies or an appreciation of the fact that during the past three years rates have been lowered somewhat, both rail and lake hauls, to the aid of the live stock industry. The fact remains, however, that because of the high freight rates less grain from the prairie provinces is consumed in the live stock areas of British Columbia and the five Eastern provinces than would otherwise be the case. Many of the local freight rates are apparently out of line with the value of product. Competitors

in other countries still have a preferential export rate. This is a most involved contentious problem but I believe that there is hope for solution.

We as technical men have not made our contribution in a survey of needs as a basis for transportation companies' action. We as technical men interested in live stock have not been active in pressing for better distributing agencies of grains and mill feeds.

May I recall to your attention the excellent start in this direction made through the activities of the coarse grain pool of Western Canada in which existing elevators, such as Prescott, Montreal, Sorel, etc., were used as a base from which ground mixed grains might be distributed by truck or train in any quantities desired. The greatest saving in this was not in doing away with the middleman but in the transporting of these grains at the lowest rate of the year and the guaranteeing of a year's supply.

Another advantage in this trade, although it might appear disadvantageous to many, was the fact that it was essentially a cash sale.

The discontinuance of this service which was becoming so well established was in my opinion a most detrimental step, for not only did it cease to distribute Western grains, which had its influence on the surplus wheat and coarse grain situation, but it discouraged the liberal feeding on the part of Eastern farmers, which in turn had its influence on production.

My recommendations then under this problem of Feeds and Feeding of live stock are as follows:—

1. That this Society undertake directly a survey of forage production in every province.
2. That this Society particularly make a thorough survey of pasture and range conditions involving carrying power and improvements needed.
3. That this Society make a thorough survey of the live stock areas in Canada where the purchase of concentrates is advisable as a basis for thorough study of freight rates.
4. That this Society respectfully recommend to each of the provinces where feed boards or councils do not exist that these be created.
5. That the Society recommend to all provinces having Feed Boards or Councils that the same should extend their activities in relationship to the above mentioned surveys and educational work in connection with improving forage, pasture and concentrate requirements.
6. That as a result of the survey of concentrate needs in various live stock centres, this Society recommend to Provincial and Federal governments, as well as organized industries, that feed distributing agencies of a nature somewhat similar to those established by the coarse grain pools be established.
7. That in connection with beef cattle from the ranges, the Society actively co-operate with other agencies, including Provincial Departments, toward working out a contract satisfactory to both rancher and feeder for contract grain finishing of baby beef or older cattle.

REGIONALIZING PRODUCTION

Is it not possible for technical men, members of this Society, working in every province in Canada to clearly define the areas in each province where due to natural conditions, markets and other factors, it would seem advisable to direct production actively toward certain types and breeds of cattle? In asking this question, I have on more than one occasion met the criticism that any coerced effort toward directing production along certain lines is inadvisable in that it destroys the initiative and independence of live stock farmers. On the other hand, it must not be forgotten that many of our governmental policies for the aid of live stock producers have been developed as corrective measures, corrective of former errors in departmental assistance and guidance as much as carelessness or malpractices on the part of the grower. May I cite one example.

During the past twenty-five years many districts formerly devoted largely to beef cattle changed over to dairy cattle. With the depressed prices of dairy products in recent years many farmers in both Eastern and Western Canada have purchased an inferior type of beef sire to head their herds of grade dairy cattle. The offspring are finding their way into our beef markets either as low grade feeder cattle or inferior partly finished beef. This product reaching large proportions in Canada probably has a greater influence on overloading the beef market with a low grade product, discouraging consumption of beef in Canada, and discouraging exports, than many other more commonly recognized factors.

Again in our bull purchasing or bull loaning policies our Federal and Provincial Governments should use the power which they obviously have to refuse assistance in clearly defined dairy areas, beef cattle areas, or dual purpose cattle areas, providing the applicant applying for aid chooses a sire detrimental to the best interests of the district.

Surely in addition thereto there should be initiative on the part of professional men to determine what might be best for any community in the region in which they are working. Unfortunately the majority of departmental officials fight shy of definite advice to individual farmers or groups of farmers in this matter. The initiative has been left to a very great extent to the various breed societies and the way in which these have developed their breed in various districts has been responsible to a large degree for successes as well as failures. Unfortunately now we reap the harvest of the failures and some of these are very serious.

I consider it the duty of this Society to make a careful survey within each province and make clear cut recommendations as to the areas best suited to different kinds of live stock production.

Perhaps more as a basis of argument than anything else, I should like to offer the following observations based on the opinion of those whom I consulted in each of the various provinces.

Nova Scotia.—1. *Beef Cattle.*—Areas in the vicinity of marsh land, such as the Amherst, Port Williams and Windsor Forks areas, might well be developed along the lines of commercial beef cattle. The greatest detriment to this development is the tendency to sell hay from the farms, a most profitable undertaking when hay prices are high. Yet the future is certain to be that of cattle production of some sort. In this connection

I would particularly emphasize the value of dual purpose cattle of the very fleshy nature.

2. *Dairy Cattle.*—The opinion of departmental officials is that the balance of the province should consist of dairy cattle. It is my opinion that this is generally correct although there are many areas which cannot depend on the city milk trade and where for creamery purposes dual purpose cattle of a fleshy nature would serve better than existing dairy breeds. Only a careful survey would determine the accuracy of this opinion.

Prince Edward Island.—Generally speaking this province is best suited to dairy production. To the few farmers who because of their forage conditions would prefer beef cattle, I would recommend only a fleshy type of dual purpose cattle.

New Brunswick.—Generally speaking this province is best suited to dairying and this is the opinion of Federal and Provincial officers in that province. Provincial government assistance toward the establishment of modern creameries, which up to the present have not had very profitable returns, has now led to the establishment of cream gathering routes.

Two districts, namely Harvey and Stanley, are noted as Jersey centres. Sussex is noted as an Ayrshire and Holstein centre.

Two areas formerly essentially beef producing districts deserve careful analysis. The counties of Westmoreland and Albert still produce the most of the good quality beef found in the province. These are well suited to beef production because of marsh lands and the production of hay and pasture. Unfortunately the most of the beef produced is of relatively low quality due to a certain mixture of dairy breeding, lack of sufficiently good sires, and other influences. Nevertheless the farmers are beef-minded.

The counties of Carleton and Victoria during the period of maximum certified potato production have neglected live stock which they must now have. Authorities are divided as to whether these should become strictly dairy districts, beef finishing districts, or whether a fleshy type of dual purpose cattle should be produced therein.

Quebec.—This province has become very highly specialized in dairy production, perhaps too highly specialized. Nevertheless there are certain groups of counties in which a fleshy type of dual purpose cattle should be developed. It is suggested that such counties are Megantic, Richmond, Stanstead, Sherbrooke, Compton, part of Arthabasca, Drummond, Wolfe, Frontenac, Brome, Hull and Argenteuil, also certain centres in Lake St. John, Rivière du Loup and Rimouski.

It is suggested that finishing of high class beef cattle in winter might well be developed by certain farmers in the Montreal district who have reasonable areas of land and who are now getting most of their revenue from market gardens on a smaller scale.

Obviously this province should be carefully surveyed from the standpoint of beef finishing, dual purpose cattle production and dairy production.

Ontario.—The problem in this province is not dissimilar to that of Quebec. There are certain defined ranching territories, most of our undeveloped country and a certain portion of the very choicest parts of Old Ontario, where beef raising is traditional, where only beef cattle should be used. On the margins of these areas only high class fleshy dual purpose cattle should be encouraged.

What has already been said regarding the production of low grade beef cattle of mixed breeding certainly applies to many areas in Ontario where formerly high class finished beef or feeder cattle could be bought in large numbers. Even in the past fifteen years well defined beef areas have had an introduction of dairy blood to the detriment of the kind of cattle now available. One thinks of such areas as Manitoulin Island, certain areas in the upper reaches of the Ottawa River and elsewhere.

There is no clearly defined policy for that large area known as the clay belt which has its climatic limitations yet has certain advantages in that it might well be developed into a profitable stopping-off point for store cattle from Western Canada for the economic use of the rich pastures and the valuable leguminous hays which can be grown so easily and profitably in these areas.

Manitoba.—It might be said generally of the three prairie provinces that aside from the ranching areas and the relatively small number of good breeders of beef and dairy cattle elsewhere, Western farmers are not yet livestock-minded. Perhaps this could be better understood when reviewing our production increases over a period of years from 1900 to 1932. During this period wheat production for all Canada increased some 625% while cattle production increased only 43%. However, during this period of 32 years or more, cattle production in Western Canada has increased but because of a lack of clearly defined areas where the best types and breeds might be developed, we find a mixture of breeds, as expressed by one of our members a "breed menagerie."

Saskatchewan.—Areas for live stock production in this province are clearly defined. It is suggested that for grain farmers desiring a few head of cattle, dual purpose cattle of the fleshy type would be ideal. There are a few areas in the vicinities of cities where dairy breeds should be encouraged. The ranching areas of the province obviously must be strictly beef cattle and the balance of the province might well be considered from the standpoint of dual purpose cattle of a fleshy nature irrespective of whether or not creameries are already established and in operation. A complete survey of this province considering the excellent soil and forage survey already conducted should be a relatively simple matter.

Alberta.—Those southern areas, particularly southeast from the Red River at Bassano to the U.S. boundary and all the Foot Hills, are essentially a range beef cattle proposition. Fluid milk areas around the towns and cities would be comparatively few and here only should strictly dairy breeds predominate. For the balance of the province, dual purpose cattle of a fleshy nature certainly should be the standard for production.

British Columbia.—A survey of this province should be relatively easy. The inter-mountain ranching areas are essentially a beef cattle proposition excepting where in certain centres irrigation makes specialized dairying profitable. It has yet to be proven, however, that the cost of irrigation, high as it is, will justify any extensive dairy husbandry since the market is confined largely to creamery products. Southern coastal regions are already highly specialized in dairying and should so remain.

The above remarks intended as a basis for discussion should, however, result in a careful survey based on a survey of feeds and feeding methods and on which in turn should be based breeding and marketing policies. It

is suggested that if a detailed survey were made, the following items might be considered:—

1. *Beef areas:*
   - *(a)* Commercial beef production and finishing.
   - *(b)* Commercial beef production and sales of feeder cattle.
   - *(c)* Areas buying store cattle for finishing.
   - *(d)* Areas which might specialize on baby beef production.
   - *(e)* Areas, if any, where pure bred herds might predominate.
2. *Dairy Cattle Areas:*
   - *(a)* For city milk trade.
   - *(b)* A general dairying programme marketing milk through cheese factories and creameries.
3. *Dual Purpose Cattle Areas:*
   - *(a)* Cows to be milked and calves pail fed.
   - *(b)* Calves to be suckled two per cow and half the herd milked during the summer season.
   - *(c)* Calves suckled and surplus milk home manufactured.

It is suggested that this Society recommend to breed associations and farmers that they thoughtfully study this problem. As soon as a survey is completed per region or province to the satisfaction of the members of this Society, the latter should recommend to Federal and Provincial governments participating in bull loaning or bull purchasing policies that assistance be given only as the breed chosen is in conformity with the best interests of the policy of production in that community. Moreover, at that time it should be recommended to governments that aid in the form of T.B. eradication, subsidies to creameries, or any other financial assistance from public treasuries be given only on the basis of conformity to the proper types of cattle within that area and that should the farmers change their breeding operations in a detrimental manner that all such aids be immediately withdrawn.

I attempted to produce a map of Canada showing in colours the various areas according to the above suggestions. Unfortunately provincial maps showing cultivated and grass areas are as yet not developed to the point where one could make a complete and comprehensive picture for Canada.

MARKETING OF BEEF CATTLE

In view of the fact that this afternoon's programme is devoted to a consideration of the marketing act, I will attempt to make my remarks on this most important topic very brief. Broadly speaking one might say that the most important difficulty in beef cattle at the present time is a price so low as to discourage proper degrees of finish or careful breeding methods. This situation is accentuated further by lack of clear cut rigid policies in breeding. The surplus of beef cattle on our markets could be more than eliminated if inferior cattle were vealed.

Still another factor is that in our dairy industry, diseases of various kinds, including T.B., abortion and mastitis, and other udder trouble cause

an enormous wastage each year, a wastage unfortunately finding its way to our markets as low grade beef or canners, thus still further glutting our markets with low grade products.

The first mentioned problem may be corrected perhaps by a vigorous campaign of an educational nature to induce all farmers with dairy cattle of mixed or dairy breeds to veal all progeny not required for the maintenance of dairy herds or to meet an immediate market for high class dairy cattle. A thorough survey of the quality of cattle on every farm in Canada if apportioned to existing extension services and other technical men working in each of the provinces should not be an insurmountable task and should result in recommendations as to what farmers in different communities should do in this connection.

Undoubtedly the best beef cattle produced in Canada in large numbers come from the Western ranges, as judged from the standpoints of breeding, type, economy of finishing, and health. It is unfortunate that no departments of governments have attempted to take some more arbitrary step to prevent nondescript beef which predominates on many of our markets from lowering the price and value of high class stuff produced on the ranges.

Again referring to bull policies, the question is asked "In connection with these policies which are not for the aid of the high class beef cattle producer on ranch or farm, but for the aid of average farmers who are not working on a clear cut long time policy for their districts, hence with mixed breeding and production resulting, is it not unfair that such policies actually appear to be detrimental to the rancher and high class beef breeder who does not benefit in any way?"

As has been mentioned there is inadequate encouragement for baby beef of a high quality. Our export trade in live cattle prefers grain fed cattle, yet low export values in the past year have often resulted in shippers or speculators getting less money than though they had sold in Canada at that time. The fact remains, however, that from a careful study of the quality of cattle shipped from various districts and a general statement as to the quality of cattle exported, that those cattle exported actually are responsible for maintaining a higher level of prices in Canada than otherwise would have existed, yet the shipper, the feeder, and even the speculator lost money for the benefit of all those who marketed their cattle in Canada of which such a high percentage was inferior.

Whether governments through the marketing act or otherwise should subsidize producers of high class stock for export or whether they should penalize the producers of the bulk of low grade beef largely consumed in Canada are debatable issues. How a clearly defined spread between choice, good, and inferior beef without a guaranteed price being established, can be undertaken is difficult to estimate. Can this best be considered on the basis of compulsory grading of all cattle going through stockyards or for export or compulsory grading of all beef in abattoirs? The beef industry of Canada is in a critical condition.

There is no doubt that the beef grading policy has already done much to educate both breeder, finisher, and consumer, yet it has not established spreads adequate to meet costs. A further consideration of this problem might even suggest a conference of beef producers and dealers in Canada similar to that successful conference of 1929.

Other suggestions which come to mind in the problem of beef marketing which are well known to most of us are as follows:—

1. Adjust the tariff with the United States in order to allow our participation again on that market.

2. Thoroughly explore the problem of chilled meat in Great Britain using as a basis high class finish baby beef in contrast to Argentine chilled beef or Argentine or Australian frozen beef. That a preliminary exhaustive exploration of this is being undertaken by a member of this Society at the present time is worthy of special note.

3. If such a market were developed it might be the means of opening up such problems as a cold storage plant in London to steady the volume of deliveries, the readjustment of ocean rates and rail rates on dressed beef, as well as on live cattle for export.

A suggestion was recently made by a Western Live Stock Association, namely that under the new Marketing Act 100,000 head of inferior cattle be slaughtered, taken off the market and destroyed, the same eventually to be paid for by a levy on cattle of high class as sold. Another suggestion which one hears even more frequently is that there be some means of rigid supervision of export cattle to Great Britain or even eventually to the United States, that this be established as a guarantee of quality of Canadian products and a basis of stimulating production of superior stock.

A statement made by one of the members of this Society strikes me forcefully. This was to the effect that although in his opinion not too much money was being spent in the stimulation of our beef cattle industry, yet too much government assistance was given in the wrong place and did not reach its fullest value in the marketing of our highest class stock and the prevention of production of low grade stock.

Still another member of this Society emphasizes the fact that in so far as British Columbia is concerned, there might be a joint federal-provincial policy created which would develop what might be termed a beef-finishing calendar. As an example, it was recently estimated that 6,500 head would be the total for the season of 1934 to be shipped from Kamloops. Of this number 4,000 would be shipped from June to August, 1,000 in October, and the balance scattered over the months of September, November and December. Since these are largely grass cattle many of which are unfinished, finishing areas in the Lower Fraser Valley might be created which would equalize the supply for the B.C. markets throughout a greater period of the year.

DAIRY MARKETING

Since the marketing of dairy products has received so much careful attention during the past three years and will actively operate no doubt under the Marketing Act, few remarks at this time are needed.

A few suggestions, which perhaps I might enumerate, have been forwarded by members.

Nova Scotia.—A local condition of cream gathering with too many trucks per route, largely demanded by the farmers, has raised costs to a marked degree. The alternative would be an attempt to get farmers to co-operate in selling on an organized basis and selling to creameries on tender.

The compulsory adoption of cream grading is suggested not only for this province but others. The 10 to 20% of low grade cream entering into manufacture places Canadian butter and cheese on an unfavourable basis to compete on either domestic or export markets with the product from New Zealand, Australia, Denmark, and elsewhere.

The education of farmers in the voluntary production of more sanitary milk is stressed.

Quebec.—One of our members emphasizes the advisability of a thorough study of the introduction of new dairy products to absorb milk surpluses emphasizing the fact that many of these are produced in Europe which are not now produced in Canada. Another suggestion made is that a premium system for the highest quality of butter and cheese for export on a five-year basis be inaugurated.

From many quarters come suggestions regarding the fixing of milk prices for both producer and consumer, but since this with other problems have been subject to many years of experimentation elsewhere and will be thoroughly considered in the application of the Marketing Act, no further comment need be made.

British Columbia.—Perhaps as a result of some of the dairy cattle recently exported as an experimental shipment, there comes the recommendation that the Federal government establish regulations and grading of dairy cattle for export as a safeguard against the occasional thoughtless or unscrupulous speculator who might easily ruin a market so carefully built up by breeders and breed associations.

Several of our members have emphasized the great desirability of continuing a careful survey of the costs of manufacturing dairy products. These have not been systematically studied or an attempt made to lower them to the same extent as with the production of milk, hence a marked influence on the returns to the producer is evident.

BREEDING POLICIES

Many references have already been made to our breeding policies and practices, hence further suggestions on this point will be brief.

It is obvious, however, to many that our assistance to our beef and dairy cattle men in matters of breeding should be placed on regional development which in turn is dependent on existing feeds, potential feeds, and the ability of the farmers as feeders.

It is suggested that before further assistance be given farmers under any of our present bull policies, etc., that a careful survey of the breeds advisable for each community be made.

Also it is wisely suggested that the individual or group receiving such government aid agree definitely to adhere to the defined policy of production for that district.

It is particularly emphasized from the standpoint of dairy cattle that a compulsory vigorous cow testing programme be conducted in every dairy community which receives financial aid from governments either in breeding or manufacturing policies.

It is suggested that in dairy communities an attempt be made to induce breed associations to agree on certain clearly defined communities, counties

or even larger areas, in which not more than two breeds—preferably but one—be promoted by them. In other words that an attempt be made to get real co-operation amongst breed associations in the defining of breed areas.

I would suggest that every member of this Society attempt to induce all others interested in putting on an educational campaign toward the preservation and use of *proven sires*. We have been preaching this doctrine in a half-hearted way for thirty years, yet to but little effect. In reality the only stumbling block is the fear of the individual farmer in handling old, strange or dangerous bulls. I have with me a blue print of a very simple safety bull pen and yard in which the attendant at no time has to handle the bull since the pen may be cleaned out by the closing of a door, cows may be bred in the yard corner using the swing gate, or the yard may be cleaned out by shutting the bull in the pen. We are maintaining aged bulls in a perfectly healthy condition at very low cost in such equipment. Actually there is no real reason why every farmer whose herd justifies bull ownership could not at little or no cost provide quarters of this kind. It is possible that some of our provincial governments which may be flush in money might even offer some small financial assistance toward the construction of such equipment as an extra inducement to the farmer to use proven sires in preference to untried younger animals often purchased at a much higher price but of speculative value.

The identification of proven sires in either beef or dairy cattle has not however, been developed by departments, as should be done. We know this from experience for we have been on the market for a dozen or more bulls of different breeds during the past few months and have discovered that even in those breed associations which have most active and efficient extension services, there is no attempt to continuously survey, list and preserve proven sires. This is a matter which should be actively drawn to the attention of breed associations.

I have no comments to make regarding existing bull loaning policies or provincial bull purchasing policies. I believe in the principle, however, that where there is a large live stock population on a farm or ranch, private ownership of bulls should be insisted upon but that in some manner the owner should be encouraged financially to a degree the equivalent of aid given to owners of small herds now benefiting by existing policies.

In measuring the value of sires in dairy and beef cattle a *progeny test* of some sort must be established. This would involve grading of bull progeny, grading of daughter progeny retained for breeding purposes, and the grading of steer progeny through the markets. How much might be established without a heavy tax on government resources would require study, but the urgent need for a standard of measurement in proven beef sires is great, and the failure of show rings to do this on a nation wide scale is well recognized.

The measurement of values of dairy bulls with existing machinery is simple. Our existing R.O.P. and Advanced Registry policies will have an enormous effect on improvement of dairy cattle and the appreciation of good pure bred sires. Probably we have not yet started to reap the greatest harvest from the excellent work of the past few years. Nevertheless a progeny test of advanced registry bulls seems to be the next step forward.

in sorting out these blood lines and sires on which we may build a real breeding programme.

Under our new Marketing Act or through the coercive influence of present bonuses, compensations and the like, more active, vigorous and continuous measures should be taken to eliminate the *scrub bull* and to *eliminate boarders* in our beef and dairy herds. Any such action should be followed by even more rigid restrictions against the rearing of such animals to still further destroy our beef market.

Have we in Canada not about reached the stage of development where *registration* practices should be altered? It is too easy and too cheap to register cull animals during the boom times. During periods of depression we suffer doubly from the propagation and recognition of such culls. It may cost more to the pure bred breeder but should almost immediately react to this benefit in the added discrimination in favour of superior stock, if we adopted practices so well established in many of the cattle breeding countries of the world, namely the identification of the pure bred calf by a tattoo or some other method and inspective and selective registration one to two years later.

Have we not reached the period when registration of dairy cattle should be based on type plus an official record of production? You will remember that the Dairy Advisory Committee under the Live Stock Commissioner carefully considered this matter in the report of their meeting in 1927.

It is obvious that further and more concerted action should be taken toward the development of community breeding clubs and improved sire areas. Almost every province now offers excellent examples of the splendid improvement that can be made by concerted effort along these lines. There is probably no better time than the present to attempt to influence the farmers to systematically cull low grade stock, for although the price for culled cattle is very low, yet feed costs especially in areas where there is feed shortage, should largely assist in getting immediate results.

It is suggested that the provincial and federal departments actively tackle this problem in whatever influence they may have on farmers through personal contacts or otherwise.

Although it appears to be a minor factor, yet speaking as an animal husbandman I am convinced that if the average farmer could be induced to keep careful breeding records of pure bred sires or females, if any, and of grade cattle in his herd, he would have a clearer knowledge of the animals themselves, which in turn would be the greatest stimulation and education toward improving the breeding practices in rigid culling of undesirable animals and better feeding and marketing practices.

Only one of our members has so far emphasized the great desirability of developing hardier and more vigorous cattle to meet Canadian and particularly Western conditions. That this should be the basis of careful study by members of this Society before any suggestions be made in reference to registration, advanced registry, or other forms of organization, is quite apparent and I leave this thought with every animal husbandman in Canada. We have all seen the craze for pedigrees or known high production influence ourselves and fellow breeders in the purchasing or retaining of breeding stock with the realization, however, that longevity and economy

of production over a number of years were perhaps doubtful due to the external evidence of lack of vigor. Surely we have reached the point where we should not countenance any pedigree without every evidence of vigor and health.

Finally I beg to leave this thought with the members of this group, namely that it should be our responsibility in co-operation with breed associations and departments to discourage the idea of making every farmer a pure bred breeder, but rather we should attempt to carefully study all farmers with whom we come in contact and who are the owners of pure bred sires or females, to sort out the few who may indicate an evidence of becoming constructive breeders.

HEALTH OF CATTLE

This matter has been already referred to and it is, I believe, admitted by all that in the broad programme of animal health, governments must assume the lead. There is no doubt that our existing problems justify our keenest support to an even more vigorous programme of research as a means of detecting and eliminating animal diseases and parasites. More exhaustive surveys of our herds throughout Canada from the health standpoint would without doubt result in a solution of many of our production and marketing problems. Eradication of diseases for which we have already diagnostic measures is an enormous problem. As one studies the live stock map of Canada from the standpoint of T.B. eradication as shown by the Health of Animals Branch at the Royal Winter Fair, one is amazed at the still all too small percentage of our cattle which may be claimed to be free from this disease. Even in these areas the high percentage of avian T.B. found in poultry flocks and the same type of organism found in our swine herds, shows the enormity of this problem. Then if one notes the millions of dollars already expended on this eradication programme with cattle alone, one questions how far such a policy may go at the expense of the taxpayers in Canada.

Nevertheless from the standpoint of export trade and human health the completion of such a programme would seem highly advisable. Should such a programme henceforth be confined essentially to dairy cattle areas producing milk for fluid consumption? Should compensation be reduced gradually to the disappearing point and the breeder made to carry the full burden?

Again we have two other diseases carrying enormous loss in our cattle. It is claimed by an excellent authority in the province of Quebec that mastitis in dairy cattle is causing greater loss in production than T.B. It is generally recognized by all who have a broad knowledge of our cattle industry that contagious abortion has for years caused greater losses than T.B.

It would appear impossible for the taxpayers of Canada to support an eradication campaign against these diseases based on heavy compensations. On the other hand, there have been excellent demonstrations as to the most economical means of gradually eliminating these diseases from the herd and certain limited services are already rendered by the Federal Government and others toward diagnosing contagious abortion, and all this is forming a ground work of education for some more vigorous policy.

Would not the policy of encouraging a greater number of practising veterinarians in every community to thoroughly train and equip themselves for a Dominion-wide programme of diagnosis and control in commercial herds even though they receive partial salary from Federal and Provincial governments for the work done, while the owners stand full loss of animals identified as diseased and a menace to their herd and public health, be about as much as we might expect the public coffers to contribute? What part we as a Society may be identified with in such a programme of education and development is problematical, yet this is but a fair example of how closely we are bound up with the problems of animal health, though we be interested primarily in feeding, breeding or marketing work.

OTHER FACTORS

I have already far exceeded the space in this programme which I deserved, hence will but mention a few of many other factors which should enter into the future development of our live stock industry.

Distribution Policies.—There are many past and present distribution policies for the assistance of districts to become established in breeding cattle and a few of these are operated at the present time. Whether or not such assistance is given based on a clear cut objective for those districts is doubtful.

There have been and are certain assistances given by departments to the distribution of cattle from stock yards to the feed lot. Is it perhaps illogical that such assistance given from stock yards should not be given equally from any other large centre where live stock may be selected, such as the ranches. There is little or no assistance given toward the distribution of feed to the live stock areas excepting to meet the emergencies of some drought stricken areas. Nevertheless, as already mentioned a well developed policy for the distribution of grains from centres which must always be grain-producing specialized areas to the centre of live stock populations would be a most worth while and constructive policy.

We repeatedly hear vigorous and even frenzied arguments as to the development of larger and more continuous movement of Western range cattle to Ontario feed lots, a policy sound in itself providing freight rates and other costs are not prohibitive. A systematic study of the principles involved and an attempt to work out a policy of sliding scale freight rates based on the value of the finished beef, has to my knowledge not yet been attempted.

These are just a few of the distribution problems both for the domestic and our export trade of live cattle and dressed beef to the markets of Great Britain or what may be our markets in the United States or elsewhere, which deserve the most thoughtful study of a group of members in this Society if the Society is to offer a continuous source of reliable opinion to our departments and governments.

Credits.—Ranchers and farmers during these times realize how little cattle either beef or dairy are considered collateral as a basis for credit in their operations. Are we as a Society studying this problem of finances in our industry? Is it not deserving of an active committee working in the closest co-operation with financial experts?

Exhibitions.—Probably no one problem gives greater concern to our live stock commissioners throughout Canada than that of our exhibitions. That they have performed an enormously beneficial task of demonstrating and even introducing better breeding stock in the communities is without doubt. That they also have been responsible for distributing disease, setting false standards, failing to conform to commercial requirements and the like we all must recognize. Nevertheless, exhibitions large and small form one of our best sources of education and contact amongst live stock men. That many of the provincial governments because of financial stress have ceased to give financial aid of any sort to smaller fairs is regrettable. That many of our wealthier provinces are continuing to give aid without a clearly defined policy as to the sphere of usefulness, the classifications, and the clientele served, is perhaps equally regrettable. That there should be a very clear cut understanding between federal and provincial governments based on a sound policy of relationship between Class A, Class B and county or township fairs appears to me to be logical.

It seems to me that here again our Society, both Eastern and Western sections, might be of distinct aid to live stock commissioners throughout Canada in defining the policies regarding the sphere of activity and the needs for and benefits from government grants to exhibitions.

I have refrained from any attempt to quote statistics which I have gathered in this connection. These I append hereto for a handy reference although none of these are entirely new.

In closing my remarks I am not attempting to recapitulate on suggestions made. I offer the above as a basis for discussion with the sincere conviction that although many of these suggestions seem to be hasty reviews yet all are in my opinion worthy of some discussion at this meeting, and an attempt should be made to organize this branch of our technical agriculturists into study bodies which may evolve plans to aid the farmers and others who constitute the industry, as well as government departments of which most of us are members and whose one ambition it is to serve the cattle industry on which the future prosperity of Canada so largely depends.

APPENDIX I.—DAIRY AND BEEF CATTLE IN CANADA SHOWING BY PROVINCES THE NUMBERS AND CLASSES OF CATTLE WITHIN EACH GROUP AND THE TOTAL NUMBERS OF ALL CATTLE, JUNE SURVEY, 1933

Province	Dairy Cattle			Beef cattle				Unclassified		All cattle
	Cows for milk	Yearlings for milk	Total	Cows for beef	Yearlings for beef	Steers	Total	Bulls	Calves	
Prince Edward Island	46,000	11,800	57,800	5,900	3,700	10,100	19,700	3,200	24,800	105,500
Nova Scotia	119,600	28,200	147,800	9,200	6,200	27,800	43,200	5,500	46,600	246,100
New Brunswick	110,500	28,400	138,900	8,900	4,900	18,700	32,500	10,100	55,100	236,600
Quebec	952,500	225,200	1,177,700	60,800	29,100	60,700	150,600	80,600	351,100	1,760,000
Ontario	1,183,200	251,800	1,435,000	69,900	249,800	133,500	453,200	62,000	573,600	2,523,800
Manitoba	363,900	109,400	473,300	*	†	100,400	100,400	20,700	211,400	805,900
Saskatchewan	480,400	141,100	621,500	137,400	59,300	181,600	378,300	38,300	408,000	1,446,100
Alberta	406,500	118,200	524,700	226,700	78,200	214,100	519,000	32,900	395,200	1,471,800
British Columbia	90,800	22,600	113,400	55,500	17,100	31,800	104,400	6,600	55,800	280,200
CANADA	3,753,400	936,700	4,690,100	*574,300	†148,300	778,700	1,801,300	259,900	2,124,600	8,876,000

*Included with cows for milk in Manitoba.
†Included with yearlings for milk in Manitoba.

Table Prepared by Dominion Bureau of Statistics.

APPENDIX II.—TABLE ID.—TOTAL DAIRY PRODUCTION OF CANADA EXPRESSED IN POUNDS OF MILK, 1933

Province	Total milk production lb.	Made into butter		Made into cheese		Miscellaneous factory products lb.	Whole milk otherwise used lb.
		Dairy lb.	Creamery lb.	Home-made lb.	Factory lb.		
Prince Edward Island.	157,371,900	45,649,000	48,888,500	3,400	6,309,000	331,000	56,191,000
Nova Scotia	473,777,800	140,460,000	142,515,800	448,000	—	13,277,000	177,077,000
New Brunswick	421,262,300	174,544,000	66,272,300	67,000	3,528,000	2,636,000	174,215,000
Quebec	4,218,981,000	332,351,000	1,531,599,000	2,800,000	284,760,000	17,968,000	2,049,503,000
Ontario	6,343,577,900	736,396,000	1,767,180,800	1,478,000	897,857,100	135,904,000	2,804,762,000
Manitoba	1,116,507,500	215,957,000	457,845,500	1,120,000	9,570,000	6,229,000	425,786,000
Saskatchewan	1,456,818,100	503,315,000	452,247,100	1,568,000	8,400,000	4,487,000	486,801,000
Alberta	1,346,402,500	292,625,000	555,987,500	2,800,000	16,072,000	5,908,000	473,010,000
British Columbia	490,132,000	51,502,000	117,816,500	281,000	6,611,500	36,696,000	277,225,000
CANADA, 1933	16,024,831,000	2,492,799,000	5,140,353,000	10,565,400	1,233,107,600	223,436,000	6,924,570,000
1932	15,917,868,000	2,503,381,000	5,009,790,000	11,503,400	1,349,872,000	219,571,000	6,823,751,000
1931	15,772,852,000	2,418,488,000	5,289,612,000	10,095,000	1,276,315,000	252,532,000	6,525,810,000
1930	15,126,459,000	2,283,152,000	4,348,431,000	9,115,000	1,333,977,000	312,800,000	6,838,984,000

Table Prepared by Dominion Bureau of Statistics.

APPENDIX III.—TABLE 11D.—PRODUCTION OF BUTTER AND CHEESE BY PROVINCES, 1933

Province	Dairy butter lb.	Creamery butter lb	Total butter lb.	Home-made cheese lb.	Factory cheese lb.	Total cheese lb.
Prince Edward Island	1,950,000	2,088,400	4,038,400	300	563,300	563,600
Nova Scotia	6,000,000	6,087,800	12,087,800	40,000	—	40,000
New Brunswick	7,456,000	2,830,900	10,286,900	6,000	315,000	321,000
Quebec	14,197,000	63,251,000	77,448,000	250,000	25,425,000	25,675,000
Ontario	31,457,000	75,488,300	106,945,300	132,000	80,165,800	80,297,800
Manitoba	9,225,000	19,557,700	28,782,700	100,000	854,500	954,500
Saskatchewan	21,500,000	19,318,500	40,818,500	140,000	750,000	890,000
Alberta	12,500,000	23,750,000	36,250,000	250,000	1,435,000	1,685,000
British Columbia	2,200,000	5,032,700	7,232,700	25,000	590,300	615,300
CANADA, 1933	106,485,000	217,405,300	323,890,300	943,300	110,098,900	111,042,200
1932	106,936,400	214,002,127	320,938,527	1,027,100	120,524,243	121,551,343
1931	103,310,000	225,955,246	329,265,246	901,300	113,956,639	114,857,939
1930	97,529,000	185,751,061	283,280,061	813,000	119,105,203	119,918,203

Table Prepared by Dominion Bureau of Statistics.

APPENDIX IV.—TABLE VID.—VALUE OF DAIRY PRODUCTION OF CANADA BY PROVINCES, 1933

Province	Dairy butter $	Creamery butter $	Home-made cheese $	Factory cheese $	Miscellaneous factory products $	Milk otherwise used $	All products* $
Prince Edward Island	332,000	428,100	21	50,700	32,700	508,000	1,487,521
Nova Scotia	1,380,000	1,339,300	3,000	—	641,000	1,172,000	4,941,300
New Brunswick	1,342,000	594,500	1,000	31,500	198,500	1,804,000	4,317,500
Quebec	2,484,000	12,397,200	25,000	2,466,200	1,792,000	22,301,000	43,193,400
Ontario	4,970,000	15,475,100	12,000	7,214,900	6,704,500	33,833,000	70,606,500
Manitoba	1,292,000	3,618,200	10,000	90,000	479,900	4,661,000	10,796,100
Saskatchewan	2,795,000	3,573,900	15,000	82,500	492,700	4,439,000	12,313,100
Alberta	1,687,000	4,156,300	23,000	155,000	421,200	5,571,000	12,723,500
British Columbia	341,000	1,158,000	5,000	82,600	1,633,800	3,727,000	7,109,400
Canada, 1933	16,623,000	42,740,600	94,021	10,173,400	12,396,300	78,016,000	167,488,321
1932	15,311,000	40,475,479	94,120	11,379,922	13,112,612	71,627,000	159,074,133
1931	21,450,000	50,198,878	108,500	12,824,695	16,550,619	78,876,000	191,389,692
1930	27,385,000	56,670,504	115,555	18,089,870	21,074,228	101,230,000	237,068,157

*The data in this column include the value of skim milk and buttermilk. For all Canada this was $7,445,000 in 1933, as compared with $7,074,000 in 1932, $11,381,000 in 1931 and $12,503,000 in 1930.

Table Prepared by Dominion Bureau of Statistics.

APPENDIX V.—DOMESTIC RATES ON GRAIN AND GRAIN PRODUCTS (PER 100 lb.)
(SUPPLIED BY BOARD OF RAILWAY COMMISSIONERS)

From Fort William to	1930			
	All rail c.	Lake and rail c.	All rail c.	Lake and rail c.
Montreal and points west thereof	37½	32½	25	20
Quebec	37½	37½	25	25
St. John.	55½	50½	40	35
Halifax	57	52	42	37
Toronto	37½	32½	25	20
Moncton	55½	50½	(a) 40	35
Truro	57	52	42	37
Fredericton	55½	50½	(a) 40	35
Sherbrooke	45	40	(b) 29	24
Charlottetown	57	52	(c) 42	37

(a) Expires end present month. If not renewed will go back to .45c. and .40c.
(b) Expires end present month. If not renewed will go back to .36. and .31c.
(c) Expires end present month. If not renewed will go back to 47c. and 42c.
From points west of Fort William add common rates to Fort William to the above.

There was some movement in coarse grains and grain products for domestic consumption in 1931 from Fort William to Halifax, Charlottetown, Yarmouth, St. John and other Eastern points by steamers used to transport sugar from St. John to the head of the Lakes. The rates were 17c. to Quebec City and west thereof, and 22c. to St. John, Halifax, Charlottetown, etc. It is understood that this business has increased. Further information is being obtained from the Halifax Harbour Commissioners.

April 18, 1934.

APPENDIX VI.—EXPORT RATES ON GRAIN AND GRAIN PRODUCTS
All Rail (per 100 lb.) (Supplied by the Board of Railway Commissioners)

From Fort William to	Wheat		Other grains		Flour and grain products	
	1930 c.	Present rate c.	1930 c.	Present rate c.	1930 c.	Present rate c.
Montreal and Quebec	34½	34½	33	33	35½	35½
	(Probably no movement under above rates)					
St. John and Halifax	35½	25	34	Barley and oats .25 Other grains .34	36½	Wheat flour .25 Other flour .36½ Oat and wheat products .26 Other grain products .37½
LAKE AND RAIL						
Montreal	25	18	25	18	25	18
Quebec	27	21	27	21	Flour .26 Other grain products .27	21
St. John and Halifax	27	21	27	21	Flour .26 Other grain products .27	Flour .20 Other grain products .21
	(present rates extended to Nov. 17, 1934)					

April 18, 1934.

APPENDIX VII.—CREAMERIES, CHEESE FACTORIES AND MEAT PACKING ESTABLISHMENTS IN CANADA, BY PROVINCES, 1932

Province	Creameries	Cheese factories	Combined cheese and butter factories	Total butter and cheese factories	Meat packing establishments
Prince Edward Island	22	13	2	37	
Nova Scotia	30	–	–	30	16
New Brunswick	23	11	–	34	
Quebec	644	432	269	1,345	36
Ontario	263	683	38	987	57
Manitoba	54	13	2	69	7
Saskatchewan	59	7	1	67	6
Alberta	91	8	4	103	7
British Columbia	33	2	1	36	12
CANADA	1,219	1,172	317	2,708	141

Table Prepared by Dominion Bureau of Statistics.

APPENDIX VIII.—SUMMARIZED STATEMENT BRANDED BEEF SOLD DURING THE YEARS, 1931, 1932 and 1933

Sales by Provinces

		Red lb.	Blue lb.	Total lb.
British Columbia	1931	1,417,617	182,744	1,600,361
	1932	1,754,319	359,695	2,114,014
	1933	2,178,250	423,495	2,601,745
Alberta	1931	473,236	1,183,470	1,656,706
	1932	629,611	1,773,206	2,402,817
	1933	984,321	2,213,766	3,198,087
Saskatchewan	1931	209,701	1,283,315	1,493,016
	1932	157,641	1,679,350	1,836,991
	1933	169,587	2,394,333	2,563,920
Manitoba	1931	560,541	2,031,600	2,592,141
	1932	985,132	1,963,056	2,948,188
	1933	1,005,195	3,169,261	4,174,456
Ontario	1931	2,474,502	4,633,816	7,108,318
	1932	2,751,913	4,906,716	7,658,629
	1933	3,855,182	9,443,954	13,299,136
Quebec	1931	1,210,961	1,579,245	2,790,206
	1932	1,256,265	3,531,864	4,788,129
	1933	1,693,100	3,152,165	4,845,265
ALL CANADA	1931	6,346,558	10,894,190	17,240,748
	1932	7,534,881	14,213,887	21,748,768
	1933	9,885,635	20,796,974	30,682,609

APPENDIX VIII.—SUMMARIZED STATEMENT BRANDED BEEF SOLD DURING THE YEARS, 1931, 1932 and 1933—*Concluded*

Sales by Months

	Red 1931	Blue 1932	Total 1933
	lb.	lb.	lb.
January	866,466	1,448,859	1,941,476
February	983,571	1,549,558	2,299,968
March	*1,199,357	†2,230,104	3,221,736
April	†1,983,022	*1,818,844	2,704,335
May	1,798,265	1,862,834	2,754,678
June	1,863,168	*1,873,354	†3,183,433
July	1,939,171	†2,080,472	*2,203,290
August	1,232,644	*1,420,278	2,666,249
September	1,336,617	†1,895,696	*2,268,707
October	1,305,252	1,615,389	2,310,955
November	1,171,797	*1,748,481	†2,780,187
December	1,561,438	†2,204,899	*2,347,595
	17,240,748	21,748,768	30,682,609

*— Change from a four- to a five-week month.
†— Change from a five- to a four-week month

APPENDIX IX

NUMBERS OF DIFFERENT CLASSES OF CATTLE EXPORTED FROM CANADA DURING THE FISCAL YEAR ENDING MARCH 31, 1934

Beef cattle over 1 year old	57,573
1 year old or less	976
For dairy purposes	2,710
For improvement of stock	2,950
	64,209

Table Prepared by Dominion Bureau of Statistics.

EXPORTS ACCORDING TO THE PROVINCE FROM WHICH THE CATTLE WERE EXPORTED AND IN WHICH THEY WERE FINISHED

Alberta	10,488
Saskatchewan	4,515
Manitoba	4,431
Ontario	31,783
Quebec	1,714
New Brunswick	75
	53,006

N.B.—Exports to the United States in 1932 show as 2,634 dairy cattle, these mostly from Ontario, and 3,052 other cattle. Exports to other countries included 170 dairy cattle and 2,985 other cattle.

Table Prepared by Live Stock Branch, Ottawa.

REPORT ON EXPERIMENTAL SHIPMENT OF CHILLED BEEF TO BRITAIN[1]

A. M. SHAW[2]

University of Saskatchewan, Saskatoon, Sask.

[Received for publication October 1, 1934]

For the past two years, the calf crop from the experimental herd kept on the Matador Ranch has been shipped to Britain alive and marketed as baby beef. In both 1932 and 1933 these consignments commanded the highest price paid for any cattle sold on the Birkenhead market during the second week of July, the price in 1932 being 9¾d. per pound (in sink)[3] and in 1933, 7½d. per pound (in sink).

A number of the carcasses of these animals in both 1932 and 1933 were forwarded to London and marketed in the Smithfield market where they readily sold at the same price as fresh killed English and Scotch beef. A quotation from a letter from one of the largest handlers of fresh killed beef in the Smithfield market indicates how this type of Canadian baby beef was received by the trade:—

"We would sum up our comments on this baby beef by saying that, in our opinion, as one of the largest handlers of Scotch beef in Smithfield, this beef has found more favour with our customers than any yet in our experience and, if the product can be organized to keep up a consistent supply, a reputation could speedily be built up for it in Smithfield that would permit of its commanding a price parallel with the choicest of our home products."

Because of this ready acceptance of fresh killed Canadian baby beef carcasses on the Smithfield market together with the well recognized fact that the heavy transportation costs involved in the shipping of live cattle from Western Canada were a limiting factor in the net returns, it was decided to make a trial shipment of chilled beef direct to London in 1934. The experiment was arranged as follows:—

1. One carload consisting of 26 head was shipped from Saskatoon alive via rail and ocean transport to Birkenhead where they were to be sold in the usual manner (in sink). Some of the carcasses were to be forwarded to London for comparison with the chilled carcasses from Montreal and Saskatoon.

2. One carload consisting of 26 head was shipped from Saskatoon via rail to Montreal where they were slaughtered, the carcasses chilled and forwarded via ocean refrigerator service to London to be sold on the Smithfield market.

3. One carload consisting of 25 head was slaughtered in Saskatoon, the carcasses chilled and forwarded by refrigerator car service to Montreal, then by ocean refrigerator service to London to be sold on the Smithfield market.

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[1] Undertaken by the University of Saskatchewan in co-operation with the Provincial Department of Agriculture.

[2] Dean of Agriculture, University of Saskatchewan.

[3] The term "in sink" is used in the British cattle markets to indicate that the animals are purchased alive, but paid for at so much per pound dressed weight. The offal is thrown out.

All three shipments were timed so that the chilled beef from Saskatoon and Montreal, as well as the fresh killed carcasses from Birkenhead, would reach the Smithfield market at the same time and be exposed for sale in the same stall on the same day in order that a careful comparison might be made. The comparison was not limited to the meat but included every item of cost involved in connection with all three methods of shipment and marketing.

In order to avoid if possible the problem of condensation which is invariably present when frozen or semi-frozen meat is removed from low temperatures and exposed for sale, it was decided to attempt to carry the carcasses at a point just above freezing, viz., 32° to 33° Fahrenheit. It was found to be impossible to carry out this plan owing to two practical difficulties.

First: on account of there being no means of circulating the air in the refrigerator cars, cooled by natural ice and salt, the inside temperature varies at different points. If an attempt were made to carry meat in sides at an average temperature of 32° F., the lower part of the sides hanging next to the ice bunkers would actually be in a temperature several degrees lower or considerably below the freezing point. To avoid this danger, it was necessary to accept a higher average temperature, one which actually ranged from 34° to 40° F.

Second: the ships have no regular range of temperatures in use between 32° and 35° F. It is quite possible for them to maintain any temperature desired, but to secure this, it was necessary to contract for an entire compartment. This was impossible owing to excessive costs involved, again making it necessary to accept the accommodation offered, viz., a 'tween deck chamber held at 35° to 40° F.

On June 20, twenty-five head were killed in Saskatoon, half of the sides being shrouded, the balance left in the natural state. The carcasses were pre-cooled for 48 hours at a temperature of 33° F. to 34° F., then wrapped in stockinette and burlap, loaded into a refrigerator car and held at a temperature which varies from 34° to 40°., until reaching Montreal, where they were loaded along with the 26 carcasses that had been prepared and handled in exactly the same manner with regard to slaughtering, shrouding, pre-cooling and wrapping at that point. The temperature of both the Saskatoon and Montreal killed carcasses at the end of the 48-hour pre-cooling period was the same, viz., 35° F., at centre of hind quarter and 34° F. at centre of shoulder.

The transfer from the refrigerator car and from the abattoir at Montreal to the ship was made on the afternoon of June 28. In the freight sheds where the transfer was made, the temperature of the air, which was very humid, was 85° F. The meat was exposed to this temperature during the time it was being stored—about an hour in all. The Saskatoon shipment arrived at Montreal in perfect condition and the whole consignment was satisfactorily hung in one of the 'tween deck chambers on board ship. The chamber used also contained a large quantity of bacon.

The ship sailed on June 29, and arrived at the Surrey Docks, London, about midnight on Sunday, July 8, too late to have the meat ready for the Monday morning market. As comparatively little business is done on Tuesday at Smithfield, it was decided to hold the beef for the Wednesday

and Thursday markets. July 9 was another extremely hot day, the humidity was high and the temperature on the docks registered 85° F. As soon as the hatch was opened up, a thorough inspection of the beef was made. Several sides were unwrapped and tested. The entire consignment was found to be in fairly good condition, no molds were in evidence, and the sides appeared dry and a good colour. The only evidence of deterioration was a very faint odor of "sourness" or "bone taint", which could be detected on some of the sides.

During the whole of Monday forenoon while the bacon, which was in the same chamber, was being unloaded, the hatch, of course, was open and, although the ship's engineers kept the refrigeration system working, the temperature was greatly raised. At noon, the hatches were sealed and not again opened until Tuesday at 4 p.m., when one-half of the shipment was removed and sent to the stalls in Smithfield market where it hung until the market opened at about 4 a.m. on Wednesday, July 11. The balance was brought out on Wednesday afternoon and sold early on Thursday morning, July 12.

By this time, "sourness" or "bone taint" that had only been slightly noticeable on some of the sides when inspected and tested on arrival, July 9, had increased to an extent that greatly lowered the price secured for the meat. None of it was condemned, the Government inspectors who inspect all imported meats simply specified that the large bones be removed from some of the hind and fore quarters before offering for sale. These instructions were carried out and the entire consignment finally sold.

The shipment of live cattle which had meanwhile reached Birkenhead landed in good condition. Sixteen of them again sold for the top of the market at 8d. per pound (in sink), the carcasses of the other ten head being forwarded to London where they were exposed for sale in the same stall with the chilled carcasses from Saskatoon and Montreal on July 11. They were readily sold at the same price as was being paid for fresh killed English and Scotch beef of similar quality, viz., 5/4 per stone of eight pounds or 8d. per pound.

These fresh killed sides were, of course, in perfect condition, but the difference in appearance between them and the chilled sides was not as great as might be expected. The latter had lost some of the bloom which is present in fresh killed meats and also was slightly drier and darker in colour. In comparing the Canadian chilled sides with fresh killed Canadian beef, and also with Scotch and English fresh killed beef, it was found that there was much less difference in actual appearance than there was between it and the frozen and semi-frozen beef of other countries.

The offal from 13 head killed in Montreal was prepared and shipped at a temperature of 20° F. in order to compare the price obtained with that secured for the offal from the other 13 head which was disposed of in Montreal. It arrived in perfect condition and fetched 63c. net per steer more than an equivalent amount sold in Montreal.

In support of this finding and also keeping in mind that this particular shipment was not in prime condition when sold and therefore could not be used as a basis, the following quotation is submitted from a statement given by the Smithfield firm that handled the shipment:—

"Had this meat arrived in perfectly sound condition, the sides would have made from 4/- to 4/4d. per stone of eight pounds (6d. to 6½d. per lb.),

and considering that on the same day Argentine chilled sides in perfectly sound condition made 2/6d. to 3/- per stone (3¾d. per lb.), the comparison is very favourable to the Canadian chilled sides."

The following detailed statements covering each method of shipment indicate clearly the costs involved. In statements No. 2 and No. 3, the price per pound is that indicated in the quotation, which appears in the preceding paragraph, viz., 6½d. per pound.

STATEMENT No. 1

RECEIPTS FROM 800 LB. STEER SHIPPED ALIVE FROM SASKATOON, SASK., TO BIRKENHEAD, ENGLAND[1]

Rail freight Saskatoon to Montreal at $1.12½ per 100 lbs.	$ 9.00		
Feed in transit	1.00		
Feed in Montreal, yardage, etc.	1.00	Sale of 440 lbs. beef.	
Ocean freight	10.80	in sink at 8d.	$73.33
Ocean feed and bedding (feed supplied Montreal less surplus). Sold Birkenhead	3.00		
Ropes, pails, etc.	.40		
Wages	.50		
Shipping Master	.05		
Tagging	.05		
Insurance on attendants	05		
Marine insurance on cattle at 50c. per $100 on $80	.40		
Handling (Broker's charge)	.50		
Birkenhead Charges —			
Government inspection at 5d. per head	.10		
Droving at 2/6 per head	60		
Keep	1 00		
Gifts at 1/- per head	.25		
Birkenhead charges	1.00		
Dock dues	.20		
Insurance at 9d. per head	.18		
Commission	2 00		
	$32.80		
Balance	40.53		
	$73 33		$73.33

[1] In this and the following statements the exchange rate is £1=$5.00.

STATEMENT No. 2

RECEIPTS FROM 800 LB. STEER SHIPPED ALIVE FROM SASKATOON, SASK., TO MONTREAL, QUE., THERE SLAUGHTERED AND SHIPPED CHILLED TO SMITHFIELD, LONDON, ENGLAND

Rail freight Saskatoon to Montreal at $1.12½ per 100 lbs.	$ 9.00	Sale at Smithfield of 440 lbs. dressed	
Feed in transit	1.00	beef at 6½d. per lb.	$57.29
Feed at Montreal	.50	Sale of offal and hide	
Killing charges	1.25	(Montreal)	3.57
Wrapping	1.00		
Weighing and insurance	.08		
Ocean freight at $1 60 per 100 lbs. on 440	7.04		
Marine insurance at 6c. per 100	.03		
London Charges—			
Quay rates at 10/- per English ton less 10%	.45		
Port rates at 2/- per English ton less 7½%	.09		
Haulage, Surrey docks to Smithfield at 2/6 per carcass	.60		
Tolls to corporation at 2/3 per English ton	.12		
Unloading charges at 1/- per carcass	.25		
Selling commission at 2d. per stone of 8 lbs.	2.30		
	$23.71		
Balance	37.15		
	$60.86		$60.86

STATEMENT No. 3

RECEIPTS FROM 800 LB. STEER KILLED AT SASKATOON, SASK., AND SHIPPED CHILLED TO SMITHFIELD, LONDON

Local freight	$ 0 50	Sale at Smithfield of 440 lbs. dressed beef at 6½d. per lb.	$57.29
Killing charge	2.00	Sale of offal and hides, Saskatoon	3.13
Wrapping	3.00		
Rail freight Saskatoon to Montreal at $1.49 per 100 lbs. on 445 lbs.	6.63		
Ice charges (approx.)	2.00		
Ocean freight at $1.60 per 100 lbs. on 440 lbs.	7 04		
Marine insurance at 6c. per 100	.03		
London Charges—			
Quay rates at 10/- per English ton less 10%	.45		
Port rates at 2/- per English ton less 7½%	.09		
Haulage, Surrey docks to Smithfield at 2/6 per carcass	60		
Tolls to corporation at 2/3 per English ton	.12		
Unloading charges at 1/- per carcass	25		
Selling commission at 2d. per stone of 8 lbs.	2 30		
	$25.01		
Balance	35.41		
	$60 42		$60 42

STATEMENT No. 4

COMPARISON OF RECEIPTS FROM SALES OF OFFAL FRESH AT MONTREAL AND FROZEN AT SMITHFIELD, ENGLAND (ONE STEER)

—	Montreal			Smithfield		
	Weight	Rate per lb.	Amount	Weight	Rate per lb.	Amount
	lbs.			lbs.		
Liver	7	$0.07	$0.49	7	$0 12	$0 84
Tongue (trimmed)	3	.10	.30	5 (untrimmed)	16	80
Heart	2¾	.03½	.10	2¾	.04	.11
Tail	—	—	—	—	—	.02
Hide	45	.05	2 25	45	.08	3.60
			$3.14			$5.37
				Less ocean freight and expenses in England		.35
						$5.02

SUMMARY OF STATEMENTS 1, 2 AND 3 (ONE 800 LB. STEER)

Killed at	Canadian expenses	Ocean expenses	English expenses	Total	Gross receipts	Net receipts
Birkenhead, England	$11.00	$15 70	$5 33	$32.03	$73 33	$41.30
Montreal	12.83	7.07	3.81	23.71	60 86	37.15
Saskatoon	14 13	7.07	3.81	25.01	60.42	35.41

SUMMARY

The results obtained in the foregoing experiment seem to justify the following comment thereon:—

1. The most profitable shipment was No. 1, where the cattle were shipped alive to Birkenhead, England, and sold in sink at that point.

2. There appeared to be little difference on arrival in the appearance or condition of the carcasses prepared in Saskatoon as compared with those prepared in Montreal.

3. Although there is little difference in the returns from the Saskatoon and Montreal lots—$1.74 per head—it is probable that a shipment killed in Montreal is exposed to less chance of temperature variation than one killed in Saskatoon and shipped to Montreal in refrigerator cars. Further, the Saskatoon beef arriving in England is four or five days older than that killed in Montreal. The latter has a better chance of arriving in good condition.

4. The temperature of the refrigerator cars is not uniform throughout the car, being lowest at the two ends at the bottom and highest in the centre at the top. Although this is perhaps not so important in the case of certain products, the range of safety in the case of chilled beef is so small that, if the car temperature is such that the sides hung at the ends are at the correct temperature, those in the centre will be exposed to a temperature very much too high.

5. It is not possible to hang large sides (over seven feet in length) in refrigerator cars owing to lack of height; and, as quartering detracts from the value of the carcass, it would seem that inland killing and shipment, chilled in sides, of two-year-old or larger animals is impossible. The same is true of the refrigeration chamber on board ship, only a few ships have sufficient head room to handle large carcasses.

6. At present prices, it would seem to be more practicable to ship the edible offal frozen to Great Britain than to sell it in Canada.

7. It is evident that the success of the Canadian chilled beef trade will be controlled by the condition of the chilled beef arriving at Smithfield. The avoidance of "souring" and "bone taint" is essential and therefore the time elapsing between the slaughter of the beef and its appearance on the stall in Smithfield should be as short as possible.

8. Time might be saved in the pre-cooling process by chilling the freshly killed beef more rapidly. In the case of the Montreal and Saskatoon lots, forty-eight hours of gradual chilling were allowed at chamber temperature, about 34° F.

9. Shipping chilled meat with other commodities in the same chamber is unsatisfactory.

10. The practice of shrouding the carcasses appears to have no commercial value in the British market. British beef is never shrouded.

11. Molds which frequently give trouble in meats held at high temperatures were entirely absent in this shipment.

12. No trouble was experienced from condensation. The meat, when removed from the refrigeration chamber to the market, did not "drip" or "sweat" in the slightest degree.

13. Close observation of various shipments under different conditions prompts the belief that only where meat is held at a temperature sufficiently low to form ice crystals in the outer layers does the question of condensation become of practical importance.

14. Forwarding chilled beef presents much greater difficulties than those encountered in the handling of a semi-frozen product.

15. Varying temperatures to which the meat was exposed during loading and transferring from cars and abattoirs to the ship, together with additional and unavoidable delay at London, in all probability was partly responsible for the unsatisfactory condition of the meat on arrival.

16. The meat was in perfect condition when leaving Montreal. On arrival in London, slight deterioration was noticeable. Whether this was due to temperature or time factors or a combination of both is not clear, although there is reason to believe that the rapidity of cooling is directly related to the condition recognized as "bone taint" in chilled meat.

17. The question of proper rate of cooling and correct temperatures at which to carry chilled meat from Canada is still to be worked out.

In conclusion, it might be said that Canadian chilled top quality baby beef is entirely suitable for the British market as far as conformation, type and finish are concerned; and, if the meat can be landed in good condition, the likelihood is that the price would closely approach that of the home-grown or home-killed product. This means that it would command a price very much higher than that ordinarily obtained for the products of Argentine and Australia. In the face of this, however, is the fact that, even though these prices could be obtained for the chilled product, this experiment has demonstrated that the same class of cattle forwarded alive will be likely to net a greater return.

ACKNOWLEDGMENTS

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SOME METHODS OF CONTROLLING THE SPREADING OF INTERNAL PARASITES OF THE HORSE

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Investigations into the prevalence of animal parasites in domestic animals during the past decade have shown that, in temperate climates, they are by far the greatest source of loss to stock owners. Unfortunately, the greater proportion of the loss is occult and consists in loss of condition, lack of growing power and inability to meet concurrent disease because of the continuous and insidious action of the parasites within the various hosts. In addition to the actual damage done to the host these parasitic worms must, of necessity, use a considerable proportion of the animal's food. Modern agriculture and transport has distributed these parasites so thickly and so generally that estimates of the loss suffered by the owners of live stock in Canada alone, must amount to tens of millions of dollars annually.

No animal is more consistently infected with internal parasites than the horse. In addition to Bots, Stomach worms, Round worms, Pin worms and Tapeworms, they are invariably infected—generally heavily infected-- with a group of blood-sucking, tissue-feeding nematodes called Sclerostomes, which live in the large intestine; the losses caused by this group alone, must reach enormous figures.

Worm parasites cannot multiply within the body. One infective stage entering the body can only become a single adult. Their eggs or larvae must, in all cases, spend some time outside of the body before re-entering, and a heavy infection, therefore, must depend on a large number of these infective forms being swallowed. These parasites lay minute eggs which pass from the host in the droppings; there, they embryonate and hatch; the small larva which emerges, feeds and moults and feeds again on the bacteria in the droppings or on the adjacent ground. It is not until it has moulted on the second occasion however, that it is capable of infecting the same or another host. This second moult takes place in about four to five days in hot weather, and a correspondingly longer time in cool weather. Once this infective stage has been reached, the larva ceases to feed, becomes very resistant to adverse influences and does not develop further until it is swallowed by a horse. After a more or less complicated migration in the animal, depending upon the species of Sclerostome involved, it settles down and develops to sexual maturity; it is during this part of its life cycle that it does the greatest damage to the host.

While it is possible to effectively destroy the adult worms within the horse, it is, unfortunately, completely impossible to destroy the migrating forms. Accordingly, to minimize the damage which these parasites do, it is necessary to attack the worm during its stages *outside* of the animal. As we have seen, these consist of the egg, the free-feeding larvae and the infective larvae. The egg, *before* embryonation, is very resistant to the

[1] Research Assistant and Honorary Research Associate

[2] Paper read before the Canadian Society of Animal Product—Eastern Section at Macdonald College, P.Q., June 27, 1934. Investigation conducted with financial assistance from the National Research Council of Canada.

extremes in temperature and climate encountered in this country. Even a severe winter such as we experienced this year, did not kill sclerostome eggs; it merely inhibited development. The embryonated egg and the free-feeding larval stages are much less resistant, however, and are relatively easily killed. The infective larvae, on the other hand, are again extremely resistant to drying, cold and heat—these larvae are so resistant to drying that they have been collected from the dust collected on windowsills of stables unused for two years and have been easily revived on moistening.

The problem confronting us at the moment is to develop a method of killing those free stages in the manure, so that treated manure would be non-infective for horses and, at the same time, would not lose its manurial properties. The agencies suitable for doing this may be grouped as physical or chemical.

CONTROL IN STABLE AND FARM YARD

A. Physical Agencies

(1) ***Drying.***—Drying of freshly passed manure, spread in thin layers and exposed to the sun, is practicable only in dry tropical climates such as the Sahara. Manure treated in this way is useless as manure, but is valuable in those regions as fuel. Accordingly, its practicability is limited to those areas where the fuel value is more important than the fertilizing value, or in military encampments, where its preservation is a matter of secondary importance to its disposal; it is not practical in Canada.

(2) ***Freezing.***—Frequent alternate freezing and thawing can be relied upon to kill the free-living stages, but as I mentioned above, I found that the continual low temperatures experienced in Canada this year were insufficient to kill the eggs; they merely retarded development, the eggs embryonating and hatching normally in the spring.

(3) ***Heating.***—Schwartz, of the United States Bureau of Animal Industry, has ingeniously used the heat of fermentation for killing both the eggs and the larvae. A temperature of approximately 70°C. is necessary for this; such a temperature is easily reached in the *centre* of a well-packed manure heap, but the heat in the outer edges of the heap is insufficient to kill the eggs and larvae. To obviate this, Schwartz has developed a double, wooden box which maintains a more even temperature and which works quite effectively. The application of this method is limited to well-equipped stables on well-to-do farms; it is not a practical procedure on the ordinary farm because of the expense and trouble entailed.

B. Chemical Agencies

The use of a chemical disinfecting agent applied to manure is governed by the following principles:—

(1) It must be cheap and easily obtainable.

(2) It must have no deteriorating effect on the fertilizing value of the manure.

(3) It must be harmless to both plants and farm animals.

My experiments during the past eighteen months have shown that the most effective, readily available, lethal agent is urine—that of cattle being

as effective as that of horses. Soaking the manure with urine, even when diluted with an equal quantity of water, kills all the infective larvae within forty-eight hours, and most of them, within twenty-four. This agent not only complies with the three principles I have enunciated above, but has the additional advantages of *increasing* the fertilizing value of the droppings, and utilizing a valuable fertilizing agent which is generally wasted. To use it economically, stables and cow sheds should have a catch-pit into which only a limited amount of water is allowed to drain. A pump to allow the urine to be sprayed on the manure in sufficient quantities to keep it entirely wet, would be desirable. Alternatively, a water-tight concrete midden could be filled with the horse droppings, and the urine pumped into it; after two days, the latter could be run into the catch pit. If such a midden were built, five feet deep and nine feet broad, with its top projecting two feet above the level of the road, carts could be easily filled by hand from it. On most farms it would be necessary to have two such middens, or one divided into two, one half being filled while the other was being treated. Urine appears to be equally lethal to the larvae of strongyle worms of ruminants, and the manure from the stables of sheep and cows could easily be rendered parasitologically safe in an identical manner.

Having discovered that natural urine was an effective agent for destroying nematode larvae in manure, experiments were conducted to ascertain the action of chemical substances—mostly artificial fertilizers—easily available to farmers.

Urea, which is one of the main constituents of urine, is nowadays manufactured synthetically as a nitrogenous artificial fertilizer. As a lethal agent against worm larvae, it proved to be of great efficiency, half a gram sterilizing 40 grams of horse faeces in forty-eight hours. Probably because of more effective mixing, it is more lethal in solution than in the dry state. Like urine, Urea enhances the fertilizing value of the natural manure.

Nitrate of Soda, *Sulphate of Ammonia* and *Muriate of Potash*, are also lethal, in practical concentrations, when tested on small samples. When used in bulk, however, they very quickly become ionized and the lethal action almost entirely disappears. Solutions again are more effective than solids, probably because of the more efficient mixing. The use of any of these three substances would necessitate large quantities and very efficient mixing.

Other substances used as fertilizers, such as *Ground Limestone* and *Superphosphate* have little, if any, action on the worms. *Hydrated Lime* is lethal, but its action on the manure and the difficulty of handling make it useless for this purpose.

Common salt has some lethal action but it has the great disadvantage of adding little value to the manure; accordingly, unlike the others, none of its cost can be recovered in benefit to crops.

This method of treating manure with urine or urea, if applied to *all* horse droppings, could be relied upon to completely exterminate this group of parasites. It is impossible, however, to collect droppings from the roads and, especially, from the pastures. Accordingly, a series of experiments has been commenced to find if similar applications of physical

agents, artificial fertilizers or other chemicals to manure *on fields* has any effect on the sclerostome larvae.

FIELD CONTROL

(A.) Physical Agencies

In addition to those discussed above, another physical agent may be employed on the field. The infective larvae do not feed but live entirely on fat, glycogen and so on, stored up during the free-feeding period. Once this food store is exhausted, the larvae die. If kept quiet, under laboratory conditions, I have been able to keep them alive for over eighteen months, but their possible active life-span is probably longer. However, moderate heat and light stimulate them to activity and the more *active* they are the shorter the time they live. Consequently, repeated harrowing of the fields to break up the manure, exposes the larvae to physical agents and so *reduces* the life. This method however, cannot be relied upon to *eradicate* the worms.

(B.) Chemical Agencies

The same chemicals (including urine) used above, applied, in *practical quantities*, to experimental grass plots containing horse manure in the proportion of two tons per acre, have so far failed to kill larvae within a week. A similar failure was obtained with 1% and 2% *Copper Sulphate.* These experiments however, are being continued.

Another source of infection lies in larvae developing in small quantities of droppings which have been overlooked in the stables. In practice, this is a very serious source of infection and it was decided to ascertain the value of various standard disinfectants in killing infective larvae and so reducing infections. *Dakin's solution* and its commercial variants, 0.66%, and 1% *Lye* and 2% *Permanganate of Potash*, applied for short periods all fail to kill the larvae. Even 2% *Creolin* requires some hours to destroy the larvae. The most effective disinfectants which I have tested so far are 3% *Lye* and 5% *Lysol*, both destroying all larvae in faeces within an hour. These disinfectants have a similar effect on sheep-worm larvae. These experiments are being continued.

ACKNOWLEDGMENTS

I wish to take this opportunity of thanking my colleagues Dr. R. R. McKibbin and Prof. L. C. Raymond for their valuable assistance and advice during the course of this investigation.

THE MOST PRACTICAL FIELD AND LABORATORY TESTS FOR DETECTION OF MASTITIS[1]

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Mastitis or garget is a bacterial infection of the udder caused most frequently by *Streptococcus agalactiae*. The incidence of the subclinical form (which is mainly characterized by changes in the milk) in high producing herds is astonishing. It is probably related to high milk production and brought about by an overworked physiological function lowering the resistance of the mammary gland to invading micro-organisms.

To-day the streptococcical mastitis is considered as one of the most frequently occurring and, from an economic standpoint, perhaps one of the most important of all the bovine diseases. Conservative estimates of many countries indicate that at least one-third of the cows of the high producing herds are affected with this disease. Only few of the great herds have been found free of mastitis. In some herds the infection runs as high as 90%.

In mastitis not only the quantity of milk is reduced, but the quality is changed in its chemical, biological, and other aspects The most commonly used tests of mastitis are based on the determination of some of these milk alterations The most important alterations in the milk, caused by mastitis, are the following ones, which are listed in the order in which they can be most readily utilized for a practical and rapid diagnosis:—

(1) Chlorine increase, which permits the chloride field or laboratory test.

(2) pH increase or sometimes decrease, and lowered acidity which permits the pH field test and titrable acidity laboratory or field test.

(3) Catalase increase allowing the catalase field or laboratory tests.

(4) Cells increase, demonstrable by the leucocytic test, or macroscopic or microscopic sediment test.

(5) Diminishing of the sensibility to rennet, and appearance of soft curd.

(6) Presence of streptococci or pathogenic bacteria in incubated or non-incubated aseptically taken milk samples.

(7) Lactose decrease demonstrable by lactose field or laboratory test.

(8) Presence of clots as shown by the black cloth filter or strip cup tests.

(9) Visible abnormalities or changes in the character of the milk.

The above are the milk alterations which offer the most practical methods for detecting mastitis, as we have been convinced by the testing of approximately 8,000 samples of milk from separate udder quarters in the last 6 years.

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[1]Paper read before the Canadian Society of Animal Production—Eastern Section, at Macdonald College, P.Q., June 27, 1934.

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Other alterations in the milk which are not of as practical importance for diagnosis, are the following:—

Fat often decreased.
Casein always decreased, and probably changed in its character.
Heat coagulable albumin, increased.
Solids non-fat decreased.
Ash decreased.
Calcium and potassium decreased.
Sodium increased.
Electric conductivity decreased.
Viscosity ordinarily decreased.
Water percentage increased.

From the above outline we can see that the milk substances elaborated by the glandular cells are decreased in the diseased udder, and that the substances due to inflammatory reactions, *i.e.*, chlorine, leucocytes, catlases, etc., are increased. We can see also that the chemical and biological tests are listed as more practical and effective for diagnosis than the bacteriological ones.

All these tests, especially the chemical and biological tests, give their best diagnostic results when employed in the milk of individual cows, and preferably in milk of separate quarters and in fresh milk, except the chlorine test which can be used in old milk. Chemical alterations cannot be detected as well by studying the mixed milk of many cows or even of the four quarters, if, as it most frequently occurs, only one or even two of the quarters are affected. It is because of this, that diagnoses with mixed milk cannot be taken as definite. Although it is very important that the tests be carried out with the milk of each quarter of the udder separately, by the use of certain tests, however, mastitis may be detected in mixed milk if this milk contains approximately 10% of mastitis milk of diseased udders.

One of these tests, which is described later, may suffice, if clearly positive, to establish the diagnosis of the disease. But no one alone is 100% efficient, and the accuracy of the diagnosis increases by using simultaneously two or three or many tests.

Besides these tests based on the altered quantity and character of the milk, palpation of the udder, after having been emptied, offers also a means of diagnosis when the disease has progressed to a point where noticeable induration of the tissues is found.

The order in which we usually proceed to test a herd for mastitis is the following: -

(a) pH.

(b) Rapid catalase.

(c) Rapid chlorine test in the stable, testing every cow on each separate quarter, and after this,

(d) The black sieve cloth test.

With these four tests, but especially with the first three, we ordinarily find nearly all or all the cows diseased from mastitis, and one person alone or with a helper may test in this way approximately 15 cows per hour.

After these tests we take samples from the doubtful cows and from those in which we are interested to make extended tests in the laboratories. We may also determine the comparative quantity of milk in different quarters by milking out these and measuring the quantity of milk, and by making a deep palpation in each one of the emptied quarters palpating for nodules or other indurations in the milk ducts and in the mammary glands.

The milk samples for bacteriological purposes should be taken as aseptically as possible into sterlized test tubes, and all the samples destined for the laboratory immediately cooled and kept on ice till the laboratory tests are done.

TECHNIQUE AND INTERPRETATION OF THE ABOVE MENTIONED MOST PRACTICAL TESTS.

1. The testing for pH or actual acidity

The pH value of freshly drawn normal milk is from 6 3 to 6.7. To determine this, we take one cc. or 5 cc. of milk into test tubes which are marked for these quantities. We strip directly from the teat into the test tubes, holding four test tubes in the left hand. The tubes are conventiently marked with letters (a, b, c, d,) corresponding to the quarters a and b, front right and front left, and c and d, rear right and rear left. With one pipette or reohmeter add 2 cc. of bromthymal blue to 1 cc. of milk (or 1 cc. of bromthymal blue to 5 cc. of milk) and mix thoroughly. The color change should be observed in good light. Wash the test tubes with distilled water or better with the milk of the quarters that are being tested before taking a new test. A lowering of the acidity greater than pH 6.7 ordinarily indicates mastitis in some form, particularly if this occurs in separate quarters.

A fresh normal milk gives a greenish yellow coloration, shades varying from a yellowish green to a greenish yellow. Dark green, green blue and blue colorations—shades very easily recognized and indicating a pH of 6.8 to 7 6—are definite proof of mastitis. In the last periods of lactation some cows give a pH of 6.7 to 6 9—a deep shade of green—*for each quarter* (old milk or retention milk) and cows in the first period of lactation give a pale yellow coloration *for each quarter;* also colostral milk. Without exception, when a pH of 6.8 or more (colour, green-blue with bromthymol) was found *in separate quarters*, the others examination verified the result by also proving the existence of mastitis. The solution of bromthymol blue is prepared by adding 0 65 gr. of bromthymol blue to 1,000 cc. of 68% ethyl or methyl alcohol. A stronger concentration of bromthymol blue may be used; i.e., 2 gram in 200 cc. alcohol and 5 drops added to 3 cc. of milk for the determination of the pH.

Bromthymol blue paper test.—The pH test may be carried also with nearly the same accuracy using the bromthymol blue paper. This consists of small pieces of filter paper impregnated with a solution of bromthymol blue. For its use one or a few drops of milk are stripped from each teat in four separate places on the paper and the colors obtained compared with each other. The color differences are better seen by transparency.

II. Titrable Acidity of Freshly Drawn Milk

Samples of fresh milk from separate quarters are titrated with phenolphthalein as an indicator. If the acidity is found to correspond to less than 0.10% lactic acid in one quarter and higher in the other, this is a very probable indication of the presence of mastitis. Normal fresh milk shows an acidity of 0.12 to 0.15%. The titrable acidity of fresh milk is due principally to the casein and acid phosphates which diminish in diseased glands. Van Slyke and Baker first demonstrated that, in cases where the acidity was decreased and the pH was correspondingly increased, there was a decrease in the specific gravity of the non-fatty solids and an increase in the chlorine and protein other than casein.

III. Chlorine Determination

The chlorine determination test is one of the most important tests for the diagnosis of mastitis in its early stages, since the chlorine content increases in any inflammatory alteration of the mammary gland. The chlorine content of a normal milk varies from 0 8 to 0.12%. After comparing the findings of the chlorine determination with other tests in more than 5,000 samples taken from the separate quarters, we believe that a content of more than 0.14% of chlorine is always related to pathological changes in the udder. A milk having a greater chlorine content than 0.14% should be considered abnormal. In the case of a severe inflammation of the mammary gland, the chlorine content may increase to 0 3% from 0.1% as in normal milk.

The chlorine determination has this important advantage. The tests may be carried out with any kind of milk, whether it be a fresh or an old sample, or whether the sample may have been taken under the most unsanitary conditions. It is the only laboratory method for the diagnosis of mastitis whose results are uninfluenced by deterioration of the sample.

Technique for Chlorine Determination.—In our opinion, the following method is the most simple and rapid, being accurate. Forty cc. of distilled water are added to 10 cc. of milk in a small beaker. Eight to 10 drops of a 10% solution of potassium chromate are added to give a canary yellow colour to the diluted milk. N/10 silver nitrate solution is added from a burette until the first permanent deep orange color appears. The number of cc. of silver nitrate necessary to produce this change multiplied by 0.0355 will give the chlorine content in grams present in 100 cc. of milk. By the use of a suitable table the percentage of chlorine in the milk may very easily be determined. If more than 4 cc. of N/10 silver nitrate are required to neutralize the chlorine in 10 cc. of milk, mastitis is present.

Rapid or Field Chlorine Test.—The following method has been devised by Miller-Rosell, in the Bureau of Animal Industry, Washington, D.C.

Five cc. of milk are drawn directly from the quarter into a test-tube suitably graduated. Eight to 10 drops of a 10% solution of potassium chromate are added to give a canary yellow color. Four cc. of a freshly prepared N/20 silver nitrate solution or 2 cc. of an N/10 solution are added with a pipette or syringe and the mixture gently shaken.

The immediate appearance of a reddish color is indicative of a chlorine content of less than 0.14 gm. in 100 cc. of milk, and therefore is to be considered a normal reaction. If the color remains unchanged, the quarter is diseased. Since this is a quantitative reaction, the addition of 1 or 2 cc. more of the silver nitrate solution may give a rough idea of the extent of the increase in chlorine. The larger the amount of silver nitrate which is necessary to produce the red color, the more chlorine is present and probably the more intense is the disease. The salty taste of milk is also a sure sign of mastitis.

IV. Catalase Test

Catalase is a special enzyme secreted by the leucocytes which increases in inflammation. In this test the property of catalase for splitting H_2O_2 is put to use.

The majority of reports consider the catalase test as 80 to 90% accurate in the diagnosis of mastitis. Our results are in agreement with this figure. The simplicity of the test, which does not need any elaborate apparatus, constitutes an advantage over the pH test.

Technique of the Test.—Five cc. of freshly diluted 1% hydrogen peroxide is mixed with 15 cc. of fresh milk which has been well shaken to insure an even distribution of leucocytes. The mixture is then placed in a Smith fermentation tube and the closed arm filled, care being taken to exclude all air bubbles. The tube is allowed to stand for two hours in the incubator or 10 hours at room temperature. The reading is made by measuring with a centimeter scale the volume of gas which may collect in the closed arm of the tube. The results are tabulated in centimeters. From our experience, values over 0 5 cm. are to be considered as abnormal and those over 1 5 cm. as indicating definitely disease. In making this test it is very desirable to use fresh milk and freshly prepared hydrogen peroxide. However, it is possible to use milk preserved with 0 1% formalin or milk which has been held in the ice-box for 24 hours. In such cases a smaller amount of oxygen will probably result from some loss of catalase and this factor must be considered in making the reading.

Rapid Field Test.—At present the most satisfactory test for catalase is a procedure for the laboratory. However, a rapid test may be made in the stable by mixing five or six drops of milk with two or three drops of freshly prepared 9% H_2O_2 on a piece of flat glass over a dark background. The appearance of bubbles within a few minutes after mixing is considered a positive reaction. Greater accuracy can be obtained by observing this reaction with a hand lens. In view of the fact that a large number of leucocytes are required to produce such a reaction, it is probably that many cases of actual mastitis will be overlooked, if this test alone be used.

Also another rapid catalase test consists of adding 2 cc. of 3% or better 6—9% H_2O_2 solution to 5-10 cc. of milk in a test tube. On normal milk no gas formation is observed. In mastitis milk the gas and foam formation may fill the tube.

Bromthymol-catalase Test.—One very reliable *combined test* which we use constantly in the stable is the double bromthymol-catalase test. For this we ordinarily take test tubes marked for 5 cc. of milk, with a second mark for 1 cc. of bromthymol blue, and with a third mark

for 1 cc. of 6% of H_2O_2. Having the four tubes with the 5 cc. of milk of each quarter in the left hand we add 1 cc. of bromthymol and read the pH. Then we add immediately to the milk-bromthymol mixture, 1 cc. of the 6% H_2O_2 and observe the smallest appearance of gas bubbles indicative of mastitis. In the great majority of cases where the bromthymol indicates mastitis, we find also that the rapid catalase test is also positive. The 6% solution of H_2O_2 is very easily prepared by taking 20 cc. of 30% Superoxol Merk and 80 cc. of water. With this combined double field test it is very seldom that a diseased quarter remains undiscovered.

V. Lactose Estimation

The normal amount of lactose in the milk is 4 to 5 %. In mastitis the lactose-producing function is diminished or lost, and we have found mastitis milk in which lactose was entirely absent.

To determine lactose, in addition to the ordinary copper reduction test and the polariscopic methods, the following method may be useful: Mix 2 cc. of milk with 1 cc. of 25% solution of potassium or sodium-hydrate and boil in a flame for one minute until it acquires its maximum color. Normal milk gives a deep red cherry color, corresponding to 4.5% lactose. The less lactose, the less intense is the color.

VI. Macroscopic Stable Tests

The Black Cloth Filter or Strip Cup Test.---This helps much to identify mastitis in advanced cases where the milk contains flakes or clots of pus, or masses of leucocytes. The smallest amount of solid particles is a proof of mastitis.

Also every abnormal aspect in fresh milk and in the cream, as much in color, transparence, as homogeneity and flavour or taste, should be considered as suspicious of mastitis.

VII. Laboratory Tests

The Macroscopic Sediment Test.—In conducting this test, 10 cc. of milk (better warm milk) is centrifuged at 3,000 r.p.m. for 15 minutes. The supernatant fluid is then decanted and the character and quantity of the sediment observed. By this test, clean, normal milk should not give an appreciable sediment. A sediment exceeding approximately 0.1 cc. can be considered abnormal, especially if the color indicates the presence of pus (yellow) or blood (red). Clean, normal milk leaves practically no sediment in a 10 cc. sample of milk.

The Microscopic Sediment Test.—The sediment is diluted with an equal part of sterile physiological saline solution and thoroughly mixed. The contents of a loop, or, better, 0.1 cc. of this mixture is spread over an area of approximately one square centimeter, as in Breed's smear technique. The film is allowed to dry in the air and is then fixed and stained with methylene blue, or by Breed's method.

It should be pointed out that, in making the sediment test, there is some possibility of having an uneven distribution of leucocytes because of the tendency of these cells to rise in the cream layer, and, therefore, not to

appear in the sediment. This can be avoided to some extent by diluting the milk with an equal volume of distilled water and by warming the mixture to 45° or 50°C. before centrifugation. In centrifuging this mixture, it is essential that the maximum speed of the centrifuge be reached as quickly as possible.

Interpretation.—In judging the results of this test we consider normal an average of 6–10 leucocytes per field when a one-twelfth oil immersion and a 10x eyepiece is used on the microscope; over 10 indicates disease. This figure has been accepted in our studies, being based on the work of several investigators as well as on our own findings. It is believed that in perfectly healthy quarters the leucocytic content of the sediment should be considerably less, probably not exceeding three to four cells per field of sediment. *If the smears are made from unsedimented milk,* our studies have shown that *less than one leucocyte per ordinary field* of microscope is found in milk from healthy quarters.

In the sediment observed under the microscope all abnormal products of a diseased mammary gland should be carefully studied:

(a) The absence and type of leucocytes and lymphocytes. Many conclusions can be drawn from the number of the leucocytes, their morphological appearance and the evidence of phagocytic power. Not only can the diagnosis be confirmed, but to some extent the type and stage of the disease determined.

(b) The presence of erythrocytes.

(c) The number and kind of cells from the glands and their ducts, exhibiting different stages of degeneration.

(d) Particles of tissues, crystals, hematin and other pigments, caseated fibrin, mucin, etc., should be noted, but special attention should be given to the bacteria in the microscopic examination.

According to Prescott and Breed, the average number of leucocytes, determined by comparative counts on mixed commercial milk, is in the proximity of 500,000 per centimeter of milk. This number corresponds approximately to one leucocyte per field, using 1/12 oil-immersion objective and an ocular lens of 10x. Valuable contributions have been made by Udall, Johnson, Hucker and Truedel-Henning to our knowledge of this subject. After many year's comparative observations, we consider that more than 250,000 leucocytes in one cc. of milk is to be taken as a sign of mastitis.

Bacteriological Examination

Microscopic Examination of Milk Sediment.—The typical appearance of mastitis streptococci in milk or milk sediments, especially if the milk has been incubated, is well known. Long or short chain streptococci in milk drawn aseptically with the presence of a number of leucocytes are diagnostic of mastitis. Certain so-called saprophytic udder micrococci are present without exception in all aseptically drawn milk. Differentiation of these from mastitis streptococci rests on cultural studies, which are also necessary for better bacteriological tests of the disease.

A NOTE ON THE DIAGNOSING OF BOVINE STERILITY[1]

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It has been stated by many people in governmental positions that approximately 33% of the work being done by the agricultural department is related to animal diseases. With the increase in numbers of herds said to be free from tuberculosis the discussion of dairy cattle problems appears to center about disorders of the reproductive system. The two chief problems, according to agricultural agents, include the problem of sterility within the caption of Bang's Disease. Sterility does occur on a complication with any infection whether it be *Brucella abortus* or micro-organisms having a more general distribution in the genital tract.

The term sterility is used in a very compromising manner with reference to reproduction. The general application of the term actually refers to some upset in, or failure of the reproductive system to carry on in a physiological manner. If the reproductive cycle is interrupted for a matter of weeks the animal is said to be sterile. The same animal may then reproduce in quite a normal manner according to clinical observation without the previous history being used as evidence against the individual. The truly sterile animal should not reproduce at any time; it is, therefore, quite evident that the term sterility has been and is much misused.

There are a great many causes of infertility among the dairy animals and many of them are preventable. Before considering individual conditions believed, or said to be the causes of infertility let us consider the various portions of the tract of each sex under normal conditions.

In the female the ovaries carry on the process of ova production which gives rise to the symptoms known as oestrum or "heat". Among normal females this cycle requires from 18 to 21 days. It may vary slightly in either direction but should remain constant for the individual. When ovulation takes place there is a definite cavity within the ovary and considerable haemorrhage usually follows the eruption of the ovum. The cavity when filled with blood is known as *corpus haemorrhagicum*. This same body undergoes changes depending upon whether the ovum becomes fertilized or not. If fertilized it forms a *corpus luteum* (yellow body) of pregnancy; if not, it atrophies. The luteum cells develop as an outgrowth from the wall of the erupted egg sac. Some follicles fail to rupture and they may undergo regression. Such follicles are usually termed atretic follicles. The next portion of the tract, the fallopian tubes, is about one-eighth of an inch in diameter extending from the region of the ovary to the tip of the horn of the uterus on each side. In the portion near the ovary the tube is spread out into a funnel shaped process. The hollow portion of the tube is approximately the diameter of a coarse hair. During the reproductive cycle spermatazoa may travel up the fallopian tube toward the ovary while at a later stage the ovum may descend by the same path.

The uterus of the bovine species is bicornuate; it does not contain a body as does the uterus of the equine species. The horns of the uterus serve as a recepticle for the fertilized ovum and in them the foetus develops. On the inner wall there are four distinct layers of caruncles which in the

[1] Delivered in connection with a demonstration on bovine sterility presented before the Canadian Society of Animal Production—Eastern Section, at Macdonald College, P.Q., June 27, 1934.

pregnant state are called "buttons" or cotyledons. It is through the cotyledons that the circulatory exchanges occur between the developing foetus and the dam. The placenta (foetal membranes) develop in both horns of the pregnant female but they are more highly developed in the horn carrying the foetus. The external opening of the uterus is called the cervix. The cervix is a very tortuous canal and folds of membrane appear at intervals throughout its length. The vagina and external genitals do not require further explanatory remarks.

Inflammatory conditions are accompanied by signs which are considered as classical. They consist of redness, heat, swelling, pain and altered function. The causes of inflammatory reactions are numerous. In the genital organs we are concerned chiefly with mechanical injuries and infection. On the surface of the body one may readily recognize the various signs of inflammation while with internal structures the problem becomes more difficult. From the observations which may be made by every individual one cannot help but realize that inflammatory proceses within the component parts of the genital tract may inhibit the normal processes of these organs. The best example of inflammatory reaction that is familiar to all is that termed the "common cold". If the same changes occur within the fallopian tubes, uterine cornu, cervix, vagina or any other portion of the tract, is it possible to anticipate that the tissues will function in a normal manner more quickly than will the tissues of the respiratory tract? For this reason local inflammatory conditions within the genital tract bring about infertility. If the inflammatory state is corrected either by rest or medicinal care then the infertility is of short duration. If, on the other hand, the inflammatory process is of a virulent nature or reaches a chronic state or if the healing process inhibits the physiology of the tract then the sign of infertility may persist.

The importance of examining the placenta from each animal at each period of gestation cannot be stressed too greatly. A great deal of breeding disorders might be mediated by following such a procedure and keeping careful records of the placental conditions. Infertility in many cases may be attributed to anti-natal disease.

The part of the male in the picture of infertility among bovine species is frequently complex. Inflammatory processes in the testicle may result in the production of mal-formed sperms or in the cessation of sperm production or ejaculation. In the absence of spermatozoa infertility is complete. We may have all gradations of infertility in the male without danger of disseminating disease to the female yet many males with low fertility have been found extremely dangerous owing to the presence of infection in the organs.

Detection of disease conditions in the male may be accomplished through clinical examination aided by microscopic examination of the seminal fluid. Infertility of the male may also be caused by the lack of exercise, faulty nutrition, congenital and physical defects. Each case of infertility must receive careful attention and a diagnosis established only after all the evidence has been considered. The problem of infertility is an important one which involves the field of animal breeding, nutrition, management, genetics, physiology and pathology and affects both sexes indiscriminately. To accomplish satisfactory results in the attempt to cope with this problem we must have the concerted effort of all evidence having to do with live stock in the state of health.

THE RELATIONSHIP OF PARASITISM TO THE POULTRY INDUSTRY[1]

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The economic importance of the poultry industry from an individual or national standpoint merits the closest consideration. Vitally necessary to the home, and providing an efficient source of revenue in the mixed farming programme as well as in the specialized areas, the need for conservation of this great industry becomes a truism. It is estimated that the annual income derived in Canada from poultry and poultry products totals approximately fifty millions of dollars thus marking it as one of the foremost agricultural enterprises of this country.

The problems confronting the poultry industry are many and varied, and amongst these problems the presence of disease appears to be one of the main limiting factors in an otherwise profitable undertaking.

While specific infections are decimating and deadly in their effects, a more or less intimate association with this industry convinces one that internal parasitism constitutes a real, if not greater, menace to success than the former. The insidiousness of internal parasitic infestation is in itself disarming and it is not at all surprising that the average poultryman only realizes the seriousness of such a condition when in dire straits and facing severe financial loss. Unlike bacterial diseases which are of an extremely toxic and fatal nature, parasitic infestations, with a few exceptions, are not conducive to an early death. The verminous juices elaborated within the animal organism apparently possess a low degree of toxicity capable however of causing hemolysis and destruction of red blood cells. The resultant anemia and traumatic lesions caused by many species of tapeworms and round worms together with assimilation of essential food substances, induces metabolic disturbances of grave consequence. Coccidia, of which there are six known species in hens, are an exception to this rule, the destruction of the intestinal mucosa inducing an acute hemorrhagic type of disease frequently attended by a high rate of mortality.

Until the mythical belief of spontaneous generation becomes a reality, known scientific truths in regard to origin of disease must be accepted. It is perhaps trite to again quote the old axiom, "Like begets like"; nevertheless all biologic and genetic studies justify such a conclusion. Parasitological research has shown that young growing stock become infected through direct or indirect contact with older fowls which having developed a tolerance or immunity to the types of helminths or protozoa that they harbor are capable of withstanding their ravages and of acting as reservoirs of infection. In the case of nematodes, the eggs or ova passed in the droppings of such harboring hosts, may reach an infective stage with the larva still enclosed within the shell, in which location it is very resistant to all inhibitive influences such as extreme heat, cold, desiccation, etc. Or

[1] Contribution from Poultry Pathology Laboratory, co-operatively maintained by Health of Animals and Dominion Experimental Farm Branches. Presented in connection with a demonstration on parasitology before the Canadian Society of Animal Production—Eastern Section, at Macdonald College, P.Q., June 27, 1934.

[2] Animal Pathologist.

contrariwise, the perpetuation of certain species of round worms depends upon rupture of the egg shell and liberation of the larvae which undergo several moults before reaching a stage at which they are capable of reinfecting the original or infecting the new host. If peradventure, the larvae in this latter case encounter unfavourable environmental conditions, they die rapidly. In the event of the infecting parasite belonging to the cestode or trematode family (tapeworms and flukes) a secondary or intermediate host is necessary for its survival and propagation.

In poultry, a good example of this may be found in the minute tapeworm *Davainea proglottina.* In order to survive, the gravid or ripe segments containing innumerable ova each of which harbors a living embryo technically termed an onchosphere, are passed in the droppings. This onchosphere characterized by the presence of several hooklets, the movements of which under magnification are readily discernible, is ingested by different species of slugs and snails. In the bodies of these secondary hosts, the young embryo continues to develop to the cystic or bladder stage (cysticercoid). When the secondary hosts are eaten by fowls, the bladder is ruptured, thereby liberating the young tapeworm which at this time consists only of a head and neck (scolex). This developmental form attaches itself to the mucous membrane lining the intestine by means of a formidable armament consisting of four suckers and hooklets. In this position it continues to develop into the strobilate tapeworm by the production of new segments. Segmental growth takes place at the anterior or head end rather than at the tail or posterior extremity as is commonly supposed. As the anterior segments continue to grow the posterior or larger segments are pushed backward to eventually become detached when production has progressed to the stage necessary for further development.

So unusual and enthralling are the life cycles of certain parasites that a recounting of the different stages from egg to adult sounds like a fairy tale. Nevertheless, they are veritable truths and it is the possession of such knowledge acquired by close application and study that makes control at all possible. One could go on interminably outlining the intricate stages of different species of parasites, how one type of tapeworm is dependent upon the intervention of the house fly in the role of secondary host, another upon the stable fly, still others on beetles, grasshoppers and earthworms, but in the compass of a short paper, such is nor possible. Suffice it to say that parasitology furnishes one of the most alluring and captivating studies with a practical application that can be found amongst the sciences known to mankind.

Being equipped with a knowledge of the life history of many harmful and dangerous parasites, the matter of ultimate control while presenting seemingly insuperable obstacles, becomes in many instances a feasible undertaking. While anthelmintic treatment is applicable to many classes of livestock and undoubtedly serves a very useful purpose in reducing parasites to a point where they do apparently little harm, the administration of such drugs in the treatment of parasitism in poultry has not been attended with a great deal of success.

Prevention is therefore the foundation stone on which a profitable venture must rest and the application of measures designed to interrupt the

life cycles is rapidly superseding medication in this and other classes of livestock.

In outbreaks of coccidiosis where studies have shown the liberation of sporozoites to occur with some species as early as forty-eight hours after passage of oocysts, measures designed to keep the birds in confinement to permit of the daily removal of droppings for a week or ten days, have, to a large extent, robbed this dread disease of its terrors. During the period of confinement, the elevation of the feeding troughs and drinking fountains on wire mesh racks prevents the young growing stock access to feed pulled over which becomes contaminated on the floor with the infected droppings. In every case of parasitism the weapons of choice are sanitation combined with every available resource to eliminate intermediate hosts by proper drainage and control of nearby breeding places. Flies in general deposit their eggs on decomposing vegetable and animal matter and in manure piles. It thus follows that the elimination of the carcasses of dead birds, decaying organic matter and the deposition of droppings in screened or covered bins or pits will largely prevent reproduction of these ubiquitous insects, a necessary first step in parasitic control. In conjunction with this latter measure, rotation of poultry runs for the young chicks on a three year plan of interchange also proves beneficial.

All carcasses of birds dying from any cause whatsoever should be burned as the burying of such carcasess, unless to a great depth, may result in infective material being brought to the surface through the agency of earthworms, rodents, etc.

Above all, the complete segregation of the young chicks from the time of being hatched until introduced into winter quarters will accomplish more than any other plan advocated for the control of poultry parasites.

Where a flock is heavily parasitized and losses occur year after year, we are now recommending that the practice be followed of killing off and marketing all the adult birds after the peak of production has passed and a sufficient number of eggs for hatching have been selected. This seemingly drastic step has much in its favour as such a plan if followed automatically stamps out such infectious diseases as tuberculosis, infectious bronchitis, etc. Furthermore, it safeguards the young chicks from exposure to parasitic infestation through the contamination of the brooder houses and runs with infected droppings carried on the shoes of attendents or transported by other mechanical means. Fortunately so-called spontaneous outbreaks of coccidiosis do not occur in chickens hatched from eggs laid by infected parent stock nor do such parasites persist for any great length of time in the soil. This latter plan permits of the preservation of desirable blood lines and from the standpoint of the utility breeder is an economically sound policy.

REPORT OF THE POULTRY COMMITTEE[1]

CANADIAN SOCIETY OF ANIMAL PRODUCTION—EASTERN SECTION

At the last meeting of the society held in Ottawa in July, 1932, poultry for the first time constituted part of the programme. An address by Professor W. R. Graham of Guelph on some phases of nutritional research introduced the discussion of poultry problems into the society's agenda. It was felt at that time that this branch of the live stock industry should become a permanent part of the organization. In order to more definitely bring this about, a poultry committee was appointed to bring in a report at the next meeting of the Association.

In preparing the committee's report it has been the feeling of its members that a general survey of the industry in Eastern Canada should first be made and some of the more pressing problems indicated. This would possibly suggest discussion matter for this meeting and a line or lines of activity for succeeding committees. It was felt that possibly some suggestions arising from the said survey might be offered which would lead to a more co-ordinated programme of development within the industy.

Canada has rapidly forged to the front in poultry production and stands out as one of the leading countries in quantity and quality of production per unit. This development cannot be attributed definitely to any one factor or group of factors but rather to a general programme of federal, provincial and institutional work. The research and experimental work along the various branches of the industry have continually tended to lower production costs, removing many of the hazards from time to time confronting the poultryman, and have enabled him to carry on even at a greatly lowered level of prices, the result of world competition. The introduction of grading and better organized marketing conditions have further assisted in improving the general situation. Improved quality in the product resulting from advanced knowledge of poultry nutrition, improved methods of handling and grading of the product have stimulated home consumption until to-day Canada stands pre-eminently the greatest consumer of eggs per capita of any country in the world.

In spite of what has already been done in connection with the many phases of the industry, many problems still remain to be dealt with in placing the industry on the most satisfactory and successful basis from a commercial and economical standpoint.

BREEDING

Egg Production.—It is possible that during the past two decades greater progress has been made in increasing potential egg laying power than perhaps in any other phase of the industry. The work done by the Experimental Farms System, Macdonald College and Guelph, in addition to that carried on in other parts of the Dominion, has resulted in the production of individuals with world breaking egg records. The advance,

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[1]Dr. F. N. Marcellus, Professor of Poultry Husbandry, Ontario Agricultural College, Guelph, Ont. Chairman, W. A. Maw, Assistant Professor in Poultry Husbandry, Macdonald College, P.Q., E. D. Bonyman. Chief Market Poultry Inspector. Dominion Live Stock Branch, Ottawa.

This report was presented at the meeting of the Canadian Society of Animal Production—Eastern Section, at Macdonald College, P.Q., June 26, 1934.

however, in production, both individual and flock average, has possibly been more satisfactory than the progress made in establishing longevity, egg size and egg quality in addition to the relation of these factors to reproduction and hatchability.

Pure-bred vs Hybrid.—The increased attention being given commercially to the production of sex-linked chicks emphasizes the necessity for more attention on the part of the research worker, the extension specialist and departmental official to this question. Not only is it of importance from the standpoint of the hatcheryman, in determining sex in baby chicks, but it introduces the other problems of the value of hybrid vigour as compared with that of the pure-bred, and the value of and importance of such hybrids from the standpoint of their egg and meat value in relation to economical production. It further introduces the question of how far departmental officials may be justified in recommending the practice of hybridization in view of the possible risk of the breeding of such hybrids in the general breeding programme. What is likely to be its effect upon the standardization of type and quality in the breeding programme? In relation to the matter of sex determination of chicks, what about the question of sexing pure-bred chicks when taken from the incubator? More study of this problem is desirable.

Studies in Hatchability.—The work of Snyder of Guelph, as well as others, would suggest that there is a decided genetic influence in the hatchability of eggs. What is wrong with the breeding of most of our standard varieties when hatches of 30 to 60% have become the general rule? Nutrition and season are undoubtedly factors. Against this, however, we have the case of a shipment of 318 eggs of New Hampshire Reds, a non-standard variety, shipped in February from near Boston to Guelph, with at least five express transfers, and yet on the 21st of March hatching 77% of the total eggs set. The result is characteristic of the breed of birds. This question is of vital importance. At present it requires too many eggs set to produce a chick.

Standard Disqualifications.—In view of the fact that we have in Canada several national and provincial programmes of stock improvement and that in connection with all inspection work the American Standard of Perfection is the standard guide, it is of the utmost importance that the greatest possible uniformity of interpretation of the Standard should exist throughout the entire breeding and inspection service. The fact that a great majority of standard disqualifications are known to be definitely inheritable, increases the importance of such standardization of interpretation in relation to this work.

Breeding in Relation to Market Poultry.—In the field of genetics, definite problems in the inheritance of such factors as "fleshing ability" or "body shape as influencing fleshing" are important.

There is a wide variation in the body type of market poultry and probably through extensive breeding for egg production we have lost sight to some extent of the most desirable type in market chickens. Quite a large percentage have deep narrow bodies and consequently are lacking in breast meat and that plumpness so necessary to the production of market poultry. These poorly built birds are difficult and expensive to fatten

under any circumstances and they seldom, if ever, qualify for the top grades.

Studies in breed types and the influence of cross breeding on the economy of meat production are at present being pursued by W. A. Maw. Innumerable problems of relationships of various factors such as : (a) type of male used in the cross, (b) differences between reciprocal crosses, (c) egg size and growth, (d) body maturity influences, and many others on ultimate type and quality of dressed carcass, exist. The variation between the various breeds and crosses as producers of broilers or roasters is another significant problem pointing out the economy of certain types over others.

NUTRITION

The research work in poultry nutrition in relation to hatchability, chick growth, egg production and marketing, which has been done during the past five or six years has been decidedly important and fundamental. The question arises, however, in relation to all this work, whether the results obtained so far can be considered as positive in view of the fact that very little parallel study has been made of the histological, pathological and physiological reactions and the effects of the various diets under study upon the digestive system of the bird. For example, may not some of the recently recognized troubles from cannibalism, feather pulling, paralysis and other nervous reactions, be the result of a pathological condition of the intestinal tract? What is the effect of finely ground fibre on the mucosa of the intestine? Is bulk in the chick ration necessary to develop the organs of the digestive tract, and thereby affect the bird's capacity later to consume and digest feed? What is the effect on the intestines and associated organs of an excess of mineral matter? What is the physical and physiological reaction of the intestine to feed finely or coarsely prepared? What are the reactions or disturbances to other organs in the body resulting from a definite pathological intestinal condition? To what extent is the bird's digestive efficiency lowered as a result of such pathological condition?

It would appear, therefore, fundamental that a more definite histological study is vital in order to first determine in so far as possible the normal condition of the organs and tissues of the body. It is true that this has been done to a large extent on the mammal, and to a limited extent in the bird, but owing to the variations occurring as between the mammalian and avian species further work on the bird is of vital importance. The results of such a study would then permit making the necessary pathological studies which would indicate a favourable or adverse reaction to any dietary tests.

The work carried on at the Ontario Agricultural College at Guelph under the British Empire Marketing Board in co-operation with the Ontario Department of Agriculture, and the work under the Dominion Experimental Farms system, particularly at Ottawa, Charlottetown and Fredericton, have brought out some real fundamental ideas on the effect of the various cereals, the proteins, vitamins and mineral concentrates in the diet in relation to their effect upon hatchability and growth. The work on free choice feeding and the development of the cafeteria rations have opened up some entirely new lines of thought for programmes of further research in relation to the whole problem of nutrition.

The work done at Guelph in the study of turkey production and finishing for market was extremely valuable and some effort should be made to have this work resumed and carried on to more definite conclusions.

GROWTH

Growth factors as they influence the stage of growth at which poultry stock should be finished by fattening for dressing purposes present one of the outstanding economic problems facing the poultryman in determining periods of maximum profit in producing meat. Methods of management of growing stock, such as comparison of range and confinement of growing stock are of importance. A study of feed costs in relation to various stages of growth, such as the broiler stage or the small, medium and large roaster stages, as well as the immature and mature capon, is desirable.

FATTENING

Relatively little investigational work has been carried out dealing specifically with the finishing of poultry for market. The wide variation between individuals in their ability to finish in the fattening process makes necessary a special study of the selection of stock for such work. There is also the problem of the wide variation in individual bird body shape within breeds in relation to what makes a good dressed carcass. The age or size of a bird and its ability to withstand fattening, as well as the economy of fattening at different stages of growth, are of great importance for all phases of marketing, especially when the problem of percentage edible meat on the carcass is also studied. Canners of poultry are especially interested in this phase of study. Confined vs. range stock as economic units in the fattening process is also a definite commercial problem at present.

In the field of nutrition there is need for further study of the common grains in the ration, as well as a study of the varying amounts of animal protein necessary in combination with the cereals, for quality finish. Relatively little work has been done with the problem of definite protein levels in the finishing ration. There is also the need for a study of possible bleaching agents which could be used in connection with the feeding of yellow corn, in order to produce the white finish in fat and skin.

The factor of body weight loss during the early period of feeding, and how it can be most easily overcome, is another problem calling for trials in prefeeding to prevent such losses.

MARKETING

The establishment of definite Government standards, and as a result grade price differentials as established by current market demand in connection with the marketing of our poultry products, has had a vital influence in improving quality and in standardizing the marketing of poultry products throughout the entire Dominion. A recent revision of the egg grading regulations and the simplification of grades based on the results of recent work done by the Live Stock Branch and the National Research Council on egg quality and improved candling equipment—the use of the green light filter—is commendable, and the idea of simplified

grading and standardization of grade terms should be extended throughout the whole programme of grading of agricultural products.

There is still a question in the minds of some as to whether even our present grades are based entirely on actual market quality and food value. For example, what is the fundamental basis of economic quality in eggs? What determines quality in poultry flesh? Is fat the determining factor in flavour and what is the limitation in the amount of fat from an economical standpoint in cooking?

There must necessarily be a co-ordinated study of the value of poultry products from a market or consumer standpoint in connection with the studies on poultry nutrition. Unquestionably appearance, quality and flavour in the product are extensivley influenced by diet. Further, in the handling of market poultry, there is some evidence to suggest that the physical condition of the feed may have a decided influence upon the economy of gain and the grading of the finished market chickens.

The enlargement of our export markets is of vital importance and the exporting of chilled turkeys to the British market during the last two years has relieved the home market of its surplus and greatly stabilized the home market prices. During the present year, there has been a good export demand for frozen chickens and the largest shipments in years have gone forward from Canada to Great Britain. It is estimated that the home market prices have been enhanced two cents per pound as a result of these shipments.[3]

As a result of experimental work undertaken by the Poultry Division, Dominion Live Stock Branch, and the National Research Council, a large defrosting plant has been erected on the Liverpool docks in England to take care of the condensation problem in shipping chilled products. When poultry is taken into a higher temperature than it has been held at in shipping, in transit, or in storage, a heavy condensation, commonly termed sweating, occurs. This condensation interferes with the keeping qualities of poultry, destroys some of its original bloom and detracts from its appearance. By warming the poultry up in a room where the dew point or percentage of moisture is as low as it was in chill or in storage, no condensation occurs and the original bloom of the product is maintained. The condensation room erected in Liverpool is for the convenience and advantage of Canadian shippers at a small nominal fee. The advantages arising out of this innovation in the marketing of dressed poultry, developed through co-operative research, are at once obvious when it is considered that Canadian fresh killed poultry can be marketed in the Old Country with its original bloom maintained.

Other experimental work is now under way at Ottawa to determine the best shipping methods and temperatures to maintian keeping qualities of poultry in transit. The increasing of consumption on our Canadian markets is tied up directly with quality and the top grades are always in demand. We also have a growing demand for our dressed poultry in Great Britain. The demand there is also for quality and, therefore, one of our major problems in maintaining market prices is the production of poultry that will qualify for the highest grades. Shrinkage losses in

[3]Turkeys exported last two years approx. 2,000,000 lbs.
Chickens exported since Jan. 1st, 1934 250,000 lbs.

fattened and unfattened stock, holding temperatures and shrinkage, and preheating and sweating when stock is being removed from the coolers as affecting quality, are factors requiring further study.

Grade price differentials as established by current market demand through the application of Government standards are exerting a tremendous economic influence. The effect of egg grading upon consumption (raising the annual per capita consumption from 17 to 30 dozen in ten years) is well known and is largely the result of removing the question mark from the product. In the more recent regulations applying to poultry meat, the results to date would indicate a somewhat similar reaction. Upward of 500 cars of dressed poultry were inspected during the past fiscal year. During the last fiscal year (1933-34) the percentages of the different grades inspected were approximately as follows: Grade Special, 2 00%; Grade A, 34.05%; Grade B, 49.71%; Grade C, 13.99%; Grade D, 0 25%. For Eastern Canada, the percentages were as follows: Grade Special, 0 09%; Grade A, 40.79%; Grade B, 49.71%; Grade C, 8 96%; Grade D, 0 45%. Grade price differentials are generally established on the following basis:—Grade Special, 1c. or 2c. over Grade A; Grade A, 2c. over Grade B; and Grade B, 3c. to 4c. over Grade C; and the Class Milkfed 2c. more than Class Selected.

HOUSING

It must be admitted that up to the present time there has been practically no systematic study of the important problem of housing. There is a wide diversity of opinion as to what is the most suitable type—or types—of buildings for the housing of poultry. Is the single deck or multiple deck house the more economical and efficient? What should be the method of ventilation and humidity control? What are the optimum requirements in relation to these factors? While it is not suggested that types be standardized, nevertheless it must be admitted that there is much yet to be done in this regard.

SANITATION AND HEALTH

In the field of poultry disease and parasitic infestation we have possibly lagged further behind the general advancements of the industry than in any other phase. In the great majority of cases we find that the poultryman is capable of satisfactorily producing the stock, but due to the inroads of disease and parasites, his profits are entirely lost. It is definitely recognized that the most important factor in the control of such losses, apart from genetic influences, is found in proper attention to sanitation and hygiene. Even, however, under the best of conditions, the poultryman is at times called upon to meet disease outbreaks or parasitic infestations.

DISEASE CONTROL

The use of pox virus in the control of chicken pox is now definitely established as reasonably efficient. For temporary immunity or for use in case of an actual outbreak of chicken pox, the use of pigeon pox virus is advisable. For permanent immunity, the use of fowl pox live virus is preferable, particularly where the vaccinating is done during the midsummer months while the young stock is still on range. It is definitely

established that chicks four weeks of age can be successfully vaccinated, and experimental work is now in progress to determine whether or not vaccination cannot be successfully done on baby chicks. Two methods of vaccinating are of course used with these products, namely, the "follicle method" of vaccinating with the pigeon pox virus and the "stick method" of using the fowl pox vaccine. However, there still remains some work to be done in relation to the use of these vaccines, particularly from the standpoint of strains of virus used in the preparation of the vaccine. As might be expected, there is a wide variation in the immunizing value of these various strains.

Tuberculin testing for avian tuberculosis appears moderately successful where using the avian tuberculin and the interderminal wattle test. This test is now being used more and more each year but should only be used by one fully qualified to apply the tuberculin test.

In the control of fowl cholera, vaccinating appears to have comparatively little value where using the commercial vaccine. In some cases this vaccine appears to have some merit while in other cases it does not produce any reaction whatever. It is possible that the preparation of an autoginous vaccine from the specific infective organism would have more immunizing value. A great deal remains to be done with regard to possible measures of control of this particular infection, which is of extreme economic importance, because of the difficulty of identifying carriers, controlling and eradicating the disease from a plant once the infection has become established.

Pullorum disease, which for the past couple of decades has caused tremendous losses in baby chicks, is now being slowly but surely eradicated from many flocks by means of the blood test. Of the various agglutination blood tests in use at present, the so-called slow tube test is generally considered the most efficient. The rapid serum test and the rapid whole blood test with stained antigen, are being used to some extent, more particularly for the cutting down of the amount of infection in flocks, but depending upon the tube test for the diagnostic test. In many cases we find these tests being used by persons with little or no qualifications, and the result of such practice is to generally discredit the whole pullorum testing programme. Another test which is being used to some extent is the so-called pullorin test, somewhat similar in its application and reaction to the interderminal tuberculin test. Of all the co-called pullorum tests in use at the present time this latter has possibly the lowest efficiency.

There are numerous points relative to each of the above mentioned tests on which further research work is necessary. It would appear, however, highly desirable that so far as the pullorum testing work in Canada is concerned the great need is for a standardization of the testing programmes and the technique used throughout the entire Dominion. Considerable has already been accomplished in a number of the Eastern States and parts of Eastern Canada. It would appear, therefore, that the most logical procedure in connection with this work which has now attained considerable proportions in practically all provinces in the Dominion is that some action towards standardization of cultural strains, antigen preparations, antigen pH reaction and type of test should receive definite attention

and action. It is also important that some control or regulation of the application of the test and some definition of who is qualified to apply it, should be taken.

PARASITE CONTROL

The losses arising, either direct or indirectly, from intestinal parasites is perhaps greater than that occurring as a result of any other form of pathological disturbance in the bird. The losses annually suffered by poultrymen both in the way of actual mortality and of loss in production are enormous. The work that is being carried on at the present time at Macdonald College under the National Research Council is of the utmost importance and value in relation to this problem. It would appear, however, that in view of the tremendous economic importance of the whole question of losses due to parasites more work is necessary in order to bring about better and more adequate measure of control.

It is possibly advisable to keep in mind that there are many other types of infection and infestation which are causing heavy losses and reduced profits in addition to those specifically referred to. As one example coccidiosis, representing infection with one or other of several species each producing more or less specific conditions, is a disease which is possibly of equal importance to any which have been sepcifically referred to previously. This whole question of disease and parasites is one which is becoming of increasing importance and must receive more attention if we are not sooner or later to be faced with the same situation that pertains in some sections of the United States where poultrymen are being gradually forced out of business on account of the tremendous losses from disease and parasites.

In dealing with the question of disease and parasites and their control, and the increasing trouble which is being experienced in controlling such outbreaks, it may be well to keep in mind the possibility of at least some of the trouble being due primarily to pathological intestinal disturbance, the result of the kind, amount, or preparation of the constituents of the diet.

REPORT OF COMMITTEE ON ADVANCED REGISTRATION[1]

CANADIAN SOCIETY OF ANIMAL PRODUCTION—EASTERN SECTION

In presenting a report under the heading of Advanced Registration, your Committee feels that a review of developments to date in Canada is the most useful contribution it can make at this time. Advanced registration, like marketing legislation, has been a subject of much interest and discussion. They have at least one thing in common in that they arise out of a desire to improve existing conditions. Advanced registration has so far found favour with three classes of live stock. Performance records in production and breeding afford a foundation on which to establish it. Were such records available for all classes of live stock presumably some form of advanced registration would develop for many of them, because the inadequacy of present registration provision is generally recognized.

ADVANCED REGISTRY FOR DAIRY CATTLE

At a conference representative of breed associations and producers of dairy products, Federal and Provincial Departments of Agriculture, and Agricultural Colleges held in Ottawa in February, 1924, the Dairy Cattle Committee was appointed to act in an advisory capacity to the Department in regard to a number of recommendations made by the conference.

The first meeting of the committee was held in November, 1924, at which time primary consideration was given to the establishment of Advanced Registry for sires of the dairy breeds, the desirability of such a move having been strongly urged by Dr. Barton, then of Macdonald College, in an address given by him at the time of the conference. It was agreed that the underlying principle of such a service should be the rating as to type and individuality of bulls eligible from the standpoint of production credentials. It was further agreed that in inspecting bulls for Advanced Registration, the standard should be the standard of excellence of the respective breed associations, the understanding being that an animal must score an agreed percentage under each of the main divisions to be eligible.

On November 21, 1924, a meeting of the committee was held, at which representatives of the breed associations were invited to be present. At this meeting the general plan was endorsed and referred to the executives of the several associations for discussion at their respective annual meetings.

When the committee met on March 12, 1925, for the purpose of considering recommendations made by the various breed associations, and to take formal steps for the establishment of the service, it was found that the Holstein-Friesian Association was prepared to support a joint scheme only in the event of R.O.M. records being given recognition on a par with R.O.P. records, and that the majority of the other associations had stipulated against the inclusion of other than R.O.P. records except to a

[1] Dr H. Barton, Federal Deputy Minister of Agriculture, Ottawa, Chairman, A. W. Peterson, Assistant Chief Field Services, Dominion Live Stock Branch; and R. W. Zavitz, Chief Poultry Inspector, Dominion Live Stock Branch, Ottawa.

This report was presented at the meeting of the Canadian Society of Animal Production—Eastern Section, at Macdonald College, P.Q., June 26, 1934.

qualified extent. As a result, while the representative of the Holstein-Friesian Association continued to serve on the Dairy Cattle Committee, it was necessary to limit Advanced Registration to bulls of the following breeds: Ayrshire, Jersey, Guernsey, French-Canadian, and Red Poll. A parallel service, known as the Selective Registry Service, was established by the Holstein-Friesian Association for bulls of that breed.

Provision was made by the committee for the immediate establishment of two classes of Advanced Registry bulls:

Class "A"—Commercial bulls, considered primarily as suitable for the establishment of dairy herds.

Class "AA"—Bulls possessing higher qualifications as regards credentials, and rated more strictly as regards type, to be considered primarily as potential herd headers for pure bred herds.

The establishment of a third class, to be known as preferential bulls, and to be limited to outstanding sires which had demonstrated their right to be regarded as specially valuable sources of improvement in the breed, was deferred. The standard as regards eligibility for inspection was modified from time to time as experience proved advisable, and is now embodied in the attached outline.

From its inception, the Advanced Registry Service has been financed through fees for each certificate issued, and by grants received from the supporting breed associations based on their registrations for the preceding year, the maximum grant from any association being $1,000 and the minimum $100. These grants have been supplemented by an annual grant from the Dominion Department of Agriculture. Up to the present time it has been possible to have all inspection work performed by one officer, assisted in the Province of Quebec by a representative of the French-Canadian Cattle Breeders' Association.

In the nine years since the service was established, a total of 3,529 bulls have been admitted to Advanced Registry, 506 being Class "AA". The continued and increasing interest in the service is indicated by the fact that in the calendar year 1933, the number of bulls admitted totalled 689, as compared with 483 for the previous year. The increase in the province of Ontario in 1933 was very noticeable, evidently due to the weight placed upon Advanced Registry qualifications in the administration of the Premium Policy established in that province a year ago.

In the spring of 1931 the Dairy Cattle Committee recommended to the Department the formation of an Advanced Registry Board for Dairy Cattle to definitely administer the service, which by that time was well established. This recommendation was accepted, and the Board now consists of the Deputy Minister, the Live Stock Commissioner, the Assistant Commissioner, the Chief Inspector of the R.O.P. Service, and the secretary of each breed association contributing to the support of Advanced Registration.

The next development in the service will be the establishment of a preferential bull class. At the last meeting of the Advanced Registry Board, the desirability of taking final steps to establish such a class was discussed at length, and it was agreed that the Deputy Minister should act as chairman of a sub-committee to be named by himself, this sub-committee to draft standards for this class.

ADVANCED REGISTRATION

CERTIFICATES ISSUED BY PROVINCES

—	Report No. 4, January 1, 1932 — (18 months)	Report No. 5, January 1, 1933 — (12 months)	Report No. 6, January 1, 1934 — (12 months)
Prince Edward Island	34	19	9
Nova Scotia	40	34	22
New Brunswick	25	15	15
Quebec	240	306	341
Ontario	90	62	255
Manitoba	2	2	5
Saskatchewan	5	3	6
Alberta	9	8	7
British Columbia	15	34	29
	460	483	689

NUMBER OF CERTIFICATES ISSUED FROM BEGINNING UP TO JANUARY 1, 1934

	"AA"	"A"
Ayrshire	277	1,787
French Canadian	54	341
Guernsey	39	235
Jersey	105	520
Red Poll	2	—
	477	2,883

STANDARDS GOVERNING ADMISSION TO ADVANCED REGISTRATION

1. The bull must be already registered in the Canadian National Live Stock Records.

2. All scoring must be done by an inspector appointed by the Advanced Registry Board.

CLASS "A"

1. The minimum standard as regards credentials under which bulls will be eligible for inspection for Class "A" registration will be as follows:—

(*a*) The bull must be out of a record dam.

(*b*) His sire must be at least by a qualified sire or out of a record dam.

2. The bull must score at least 75% in each of the main divisions of the scale of points of the breed to which he belongs.

3. He must not be under eight months of age at time of inspection.

CLASS "AA"

1. Unless he has already qualified in the Record of Performance, a bull must have the following credentials as regards production.

(*a*) His sire must be either a Record of Performance bull, an "AA" bull, or a preferential bull, and

(*b*) his dam must have a record one-third above the standard for qualification, or

(c) his dam must have at least three records exceeding the standard by margins which when aggregated are at least one-third in excess of the average standard for qualification of the three terms included.

2. (a) His dam must score an aggregate of at least 85% of the scale of points of the breed to which she belongs, or

(b) at least four of his daughters none of which are to be younger than approaching first lactation period must pass inspection on the basis indicated in 2 (a).

3. (a) The bull himself must score an aggregate of at least 85% of the scale of points of the breed to which he belongs except

(b) when four of his daughters are already passed on the basis indicated in 2 (b) in which case an aggregate of 75% on his own score will be sufficient to pass the bull.

4. The bull must not be under twenty months of age at time of inspection.

In addition to the foregoing requirements, the following rules will apply for both Class "A" and Class "AA." Ayrshire bulls—

1. No bull born on or before December 31, 1931, shall be eligible for Advanced Registry Inspection unless his dam shall have given an average test of 3 80 per cent butterfat, or more, in any one of her lactation periods.
2. No bull born on or after January 1, 1932, shall be eligible for Advanced Registration unless his dam shall have given an average test of 4 per cent butterfat, or unless his dam shall have given an amount of butterfat that is twenty-five per cent in excess of the amount required to qualify in any one of her lactation periods, but providing that her average test is not less than 3.80 per cent butterfat.
3. Unless an R.O.P. bull is eligible through his sire and dam he will not be eligible for Advanced Registry Inspection unless four of his daughters, each from a different dam, have records which make them eligible to be the dams of Advanced Registry bulls.

CERTIFICATE

The certificate of Advanced Registration which is issued by the Advanced Registry Board will be in the form of a diploma. By arrangement with the Canadian National Live Stock Records, the regular certificate of registration for each bull admitted to Advanced Registration is conspicuously stamped to indicate his new status, and his class, A.R. No. and tattoo marks are added. In addition, the registration certificate of each of his progeny to the second generation recorded in future carries his A.R. No.

ADVANCED REGISTRY FOR PURE BRED SWINE

Previous to the year 1928 pig testing was something which swine breeders of Canada had heard about from Denmark where testing stations and breeding stations have been standard equipment for about forty years. In Canada we had a definitely organized system providing for the purchase and sale of commercial hogs according to quality; we had numerous extension policies for the improvement of our swine; we had the show ring and the individual judgment of professional men and breeders, but no measuring stick of any kind by which to gauge the actual commercial value of our breeding stock. It is admitted that there are valuable aspects of show ring competition. The show ring, however, does not place values upon the commercially important factors of production capacity, economy of gains and carcass quality. The breeding of pure bred hogs and the breeding of commercial hogs, closely interdependent as they should be,

were, under our system of establishing values, divorced from each other to a considerable degree.

As a result of this condition it was felt by some of those who were in close contact with every phase of the swine industry that there was need for a basis of testing which would provide for the breeders of pure bred swine an opportunity to test their pigs from the above mentioned commercial standpoints. In 1927 the Joint Swine Committee recommended that a system of Advanced Registry be established, and after considerable study of methods already in operation in other parts of the world, a policy which was considered applicable to Canada was evolved and has been from its inception administered by the Live Stock Branch of the Dominion Department of Agriculture, with the advice of a body representative of the swine industry throughout Canada known as the Advanced Registry Board for Swine.

The Advanced Registry Policy provides for the testing of sows registered with the Canadian National Live Stock records. Sows, to qualify, must obtain minimum scores for size of litter, and for rate of gains and carcass quality as determined by the performance of four pigs in the litter. Boars, to qualify, must sire the pigs of at least three litters which qualify their dams. To date 347 sows have qualified out of a total of 720 completing the test, or 48% Forty-four boars have been qualified.

During the first year of the application of this policy, entrants were limited very largely to the herds of our Experimental Farms and other public institutions. Since that time there has been a gradual growth in the number of entrants as indicated by the following figures:--

1929	1930	1931	1932	1933	1934
32	61	101	144	166	220

The attitude of our swine breeders towards this undertaking has been rather interesting. To the breeders of pure-bred swine who were not actively interested in catering to the show ring, the policy immediately appealed. To those breeders who had always been prominent in our larger shows, the policy cannot be said to have appealed until quite recently. Official approval of the Canadian Swine Breeders, although never definitely sought, was secured at a meeting of the Canadian Swine Breeders' Association held at Winnipeg in 1933. At that meeting a resolution was passed endorsing Advanced Registry as a valuable aid in breeding, and requesting the Canadian National Live Stock Records to include information from the Advanced Registry records on the pedigree certificate. Action was taken by the Record Board and at the present time the scores of all qualified sows are included in the Canadian National Live Stock Record for swine. The Advanced Registry number allotted to qualified animals is shown on the pedigree certificate and duplicate certificates showing the scores may be secured for sows as they qualify.

Critics of Advanced Registry for Swine have maintained that under its provisions the skill of the feeder might possibly be a bigger factor in qualifying a sow than the inherent qualities of the sow herself. The Advanced Registry Board realized the validity of this contention and for the past two years has investigated plans whereby the four pigs destined for slaughter of sows entered could be fed standard feeds under uniform

conditions at various centres across the Dominion. At a meeting held at Ottawa last February of an enlarged Board representing a broader cross-section of our swine industry the whole question was thoroughly discussed and the Board recommended the establishment of feeding stations.

The organization suggested for conducting the feeding stations provides for the establishment of Provincial Committees, the functions of which are to supervise the location and establishment of stations and to provide the necessary management. These Committees are responsibe to the Advanced Registry Board, which body, with the approval of the Department of Agriculture, lays down regulations governing standard practices, feeds, etc., and issues credentials. Eventually the machinery set up should provide a sufficient number of stations for the testing of all sows offered; for this year, however, four only will be operated, one each in the Provinces of Prince Edward Island, Quebec, Ontario and Saskatchewan.

Possibly less is known in swine than in other classes of live stock with respect to the inheritance of the various important characters. Certain qualities, however, are definitely required by the farmer producing hogs for a living. He needs sows which will wean large litters consistently year after year. The cost of feed being the largest item of expense in connection with hog production, he must have pigs which will make economical use of feeds available There being definite differences in market value based on the type and quality of the pig produced, he must have pigs which will produce a carcass of high commercial value. Our knowledge of swine genetics can hardly be claimed to have reached the stage whereby it can tell us how to produce such a pig. By testing successive generations this knowledge will be provided in concrete form—the improved pig itself. In the process the data collected should yield the story of the genetics involved in obtaining that result.

It is already possible as a result of testing to date to isolate certain strains which are consistently good and others which are consistently bad. The breeder can, by testing, supplement his own judgment of values of individuals in his herd. Our pedigree certificates today, instead of being a tabulation of names and numbers only, may be a record of performance as well, and prices paid at recent sales for animals with good records behind them indicate a practical appreciation of the value of pig testing.

PROGENY TEST PROPOSED FOR POULTRY

Poultry, by reasons of the numbers involved, the low unit cost and the rapidity of reproduction lends itself to at least two forward steps in breeding to which considerable thought has been given. First: the inclusion in the breeding programme of more, ultimately all, of the quality characters found genetically sound and required in the finished product in both poultry and eggs. Second: the stimulation of research to ascertain which quality characters are inherited and if possible how.

To date in the breeding policies only the number and size of eggs and standard requirements of the individual have been taken into consideration. There are at least ten additional characters in egg quality and six in market meat quality as well as considerations of longevity, fecundity and hatchability, which should be taken into consideration when practicable.

For thirteen years Canada has had two poultry breeding policies—Registration and R.O.P. Both have certain similar standards of qualification, taking into consideration breed type, records of production, egg weight, method and supervision of pedigree breeding. Both policies, working along these lines, have achieved good results. Flock averages in Contests and in R.O.P. flocks have reached a point around 160–170 eggs, beyond which they do not rise. Both have apparently reached their limit of production improvement with present breeding methods. The breeders have been following the usual practice of mating together the best producers, with little recognition of progeny testing in the genetical sense.

Recently the Dominion Poultry Board recommended that the desirable features of existing policies be developed into a broader, more comprehensive and more scientific programme to include: the widest possible sources for testing stock, recognition of merit on a generation basis, recognition only of sound pedigrees, inclusion of additional worth while characters as basis of qualification, advanced recognition of established prepotency, and provision for the widest possible dissemination to the farms of Canada of the blood lines established.

This programme naturally divides itself into two parts:—

1. The standards of production or qualification.
2. The recognition of prepotency in males and females.

It has recently been shown that only when the seven nearest dams of both the sire and dam have laid 200 or more eggs averaging 2 oz. each, is there a significant correlation between the dams' production and that of the progeny. A study of pedigrees under present breeding policies showed that over 50% of the birds for which pedigrees were available, were sound—200 eggs, 2 oz. average weight—for at least three generations, and further work is being done with a view to providing a sound foundation for progeny test work.

It is proposed to progeny-test qualified birds in order to segregate the truly prepotent, valuable breeding individuals. It is also proposed to make genetical studies of these results with a view to giving further direction in breeding and possible recognition of flocks which are found to have a high average of prepotency.

In such a plan the object would be not the creation of a few extremely high record individuals, valuable as they are, or even the development merely of high record families, but rather to breed individuals that will produce heavily in flock units with little culling and selection, and with their vitality, stamina and inherited production ability so definitely fixed in the entire strain that they will reproduce their kind in large number for commercial purposes.

LA PRODUCTION ANIMALE EN FRANCE ET LES RACES D'EXPORTATION[1]

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Pour saisir les caractéristiques de la production animale en France, il est indispensable d'avoir une idée nette du milieu dans lequel elle se réalise. Ce qui frappe essentiellement, à l'examen de notre pays, c'est son infinie variété.

Tous les étages géologiques semblent s'être donné rendez-vous en cette extrémité de l'Europe. Les terrains primitifs, les éruptifs, toute la gamme des terrains sédimentaires, du cambrien au pléistocène, sont représentés sur des superficies plus ou moins vastes. Le relief a été dessiné par les principaux plissements de l'écorce terrestre, du système hercynien et du système alpin. D'une part, des montagnes très usées, de faible altitude, de l'autre, des sommets très élevés atteignant tout près de 5000 mètres.

Enfin, le climat est lui-même très divers. Si l'ensemble de la France est soumis au régime océanique, en certains points se fait sentir l'influence méditerranéenne, en d'autres, par contre, règnent des écarts de température comme au centre des continents. De là, une multiplicité de "pays", ayant leur caractère propre—et la multiplicité aussi des races de bétail.

L'introduction de certaines races étrangères est venue encore accuser la diversité de physionomie de l'élevage en France: Shorthorn, Frisonne, Simmenthal, Schwitz, pour l'espèce bovine; Yorkshire pour l'espèce porcine; Mérinos, Leicester et Southdown pour l'espèce ovine, sont utilisées pures, ou bien ont servi à réaliser des races aujourd'hui bien fixées, comme Maine-Anjou, et Armoricaine, Charmoise et Ile de France, etc.

Malgré le tempérament particulariste du Français, et l'attachement à ses habitudes, il y a néanmoins tendance à l'heure actuelle très nette à plus d'homogénéisation dans le bétail entretenu, du fait de la spécialisation des races vers laquelle on tend.

Les races à aptitudes mixtes d'autrefois font place aux races de gros trait, laitières, à viande, à laine, etc., et prennent justement plus d'expansion, celles qui sont les plus améliorées, capables de s'adapter à des conditions de milieux diverses et dignes d'être exportées.

Examinons rapidement les races qui ont à l'heure présente le plus tendance à affirmer leur supériorité.

Chevaux.—Autrefois, lorsque le service de remonte de l'Armée procédait à des acquisitions importantes, et avant la vulgarisation de l'automobile, étaient nombreux les chevaux de selle et de trait léger, appartenant aux races de Pur-sang, Anglais, Anglo-Arabes, de Demi-sang, Anglo-Normand, Cobs, Postiers etc. Aujourd'hui prédominent les races de chevaux de trait lourd, les Percherons, entretenus dans le centre de la France, les Boulonnais, dans le Nord, les Bretons, dans l'Ouest, les Ardennais, dans l'Est. L'effectif de la population chevaline est de l'ordre de 3 millions d'individus environ.

[1]Sommaire de la conférence faite au Collège Macdonald le 27 juin 1934, par M Paul Thiéry, Délégué du Ministère français de l'Agriculture.

[2]Directeur.

Bovins.—Les races de travail sont entretenues dans les régions où l'Agriculture est la moins évoluée, ou tout au moins là où la petite culture domine essentiellement. Notons: la Parthenaise, dans l'Ouest, la Garonnaise et la Gasconne, dans le Sud-Ouest et le Midi. Trois races sont surtout exploitées en vue de la production de la viande: la Charollaise, dans le centre, la Limousine, plus localisée, à l'Ouest du Plateau Central et la Maine-Anjou qui résulte d'un croisement avec Shorthorn, dans l'Ouest.

Quant aux races laitières, elles comprennent: la Normande, abondamment diffusée sur un quart du territoire, la Tachetée de l'Est, dérivée du Simmenthal, qui occupe une superficie de territoire comparable, la Flamande, dans le Nord, et enfin Frisonne et Schwitz réparties en divers points.

Est-il besoin de dire que la spécialisation des races bovines n'est jamais quand même très nettement prononcée, ne serait-ce que parce que la fin de toute bête est la boucherie? Ainsi, la Parthenaise est une bonne laitière, au lait riche en matière grasse, Charollaise et Limousine sont employées pour le travail, la Normande enfin, est une remarquable productrice de viande. Au total, le troupeau bovin français, en voie d'accroissement, atteint environ 16 millions de têtes.

Moutons.—Autrefois dits bêtes à laine, parce qu'élevées surtout pour leur toison, les moutons ont, aujourd'hui surtout, d'autres fins, en raison de la baisse du prix des matières textiles.

Nous entretenons toujours de vieilles races, à aptitudes mixtes comme la Berrichonne, diffusée dans le centre et la région parisienne, où elle sert au croisement industriel, et aussi des laitières, comme Caussenarde, de Larzac, de Lacaune, répandues dans les régions où se fabrique le Roquefort.

Certains types sont spécialement recherchés pour la production de la laine. Dérivés du mérinos de Rambouillet, leur structure a été améliorée en vue de la production de la viande, et nous avons ainsi les mérinos d'Arles, du Soissonnais, de Champagne et de Bourgogne. Une race importée s'est beaucoup diffusée, c'est la Southdown.

Enfin, certaines races réalisées par croisements et bien fixées, prennent beaucoup d'expansion, remarquablement construites qu'elles sont pour la production de la viande: c'est la Charmoise et l'Ile de France (ou Dishley Mérinos).

Dans son ensemble, le troupeau de moutons a une tendance très nette à diminuer d'importance. La dépécoration sévit pour de multiples raisons et l'effectif ovin atteint à peine dix millions de têtes.

Les Porcins.—En matière production porcine, l'éleveur français cherche de plus en plus à obtenir des animaux susceptibles d'être abattus, au plus tard à 5 ou 6 mois, pesant alors une centaine de kilogrammes, et offrant le minimum de graisse de couverture. De veilles races autochtones, très améliorées, conviennent bien à cette spéculation: ce sont la Craonnaise et la Limousine. Mais l'on exploite aussi beaucoup de races importées, et notamment Middle-White, plus encore la Large White. Très souvent enfin est réalisé avec succès le croisement de races françaises par les anglaises.

L'ÉLEVAGE ET LES POUVOIRS PUBLICS

Dans le domaine de l'espèce chevaline, l'Etat intervient très activement, et l'amélioration des races est pour ainsi dire dirigée. Un étalon qui fait la monte publique doit être soit autorisé, admis comme tel s'il

ne doit pas amoindrir les qualités de la race, soit approuvé, lorsqu'il peut au contraire les améliorer. D'importantes primes d'approbation sont accordées chaque année.

Mais l'Etat intervient d'une façon plus directe encore par les étalons qu'il possède dans ses haras, et met à la disposition des éleveurs, durant la saison de monte, à des tarifs très réduits.

Le Ministère de l'Agriculture tient lui-même le Stud-Book du Pur-Sang, aide au fonctionnement des autres livres généalogiques, tenus par des associations indépendantes et organise chaque année de nombreux concours, dont le Concours Central Hippique qui réunit à Paris les représentants de toutes les races françaises.

Dans le domaine de l'Espèce bovine, l'amélioration demeure libre bien que de nombreux projets de réglementation de la monte des taureaux aient été présentés. Mais les Pouvoirs publics interviennent néanmoins d'une manière très active. D'abord par l'organisation annuelle des concours spéciaux de races et du Concours Général agricole de Paris, largement dotés de prix. Puis en favorisant le développement des syndicats d'élevage qui, en France, jouent un rôle de premier plan dans la production animale.

Le syndicat d'élevage le plus recommandable est celui qui, groupant un petit nombre d'adhérents, rayonnant sur une faible surface, est devenu propriétaire de taureaux inscrits au livre généalogique de leur race. Grâce à cette formule, le petit éleveur peut disposer d'excellents animaux reproducteurs au même titre que ceux à la tête d'une importante étable. Le taureau est acheté en commun soit après emprunt au Crédit Agricole, soit avec les versements des adhérents; puis il est confié à l'un des éleveurs qui l'entretient moyennant rétribution et recueille le montant du prix des saillies pour le compte du syndicat.

Les syndicats d'élevage se groupent en fédérations régionales dont l'activité s'exerce sur des points multiples, mais dont une des raisons principales d'existence doit être la tenue des livres généalogiques.

Le Ministère de l'Agriculture aide beaucoup naturellement les Herd-Books, qui sont gérés par des associations privées. Suivant les races, les livres sont fermés ou encore ouverts. Ces derniers font encore des inscriptions au titre initial, mais surveillent aussi la sincérité des déclarations de naissances, exigent les déclarations de saillies, et confirment, s'il y a lieu, l'inscription des animaux déclarés au titre de l'origine.

Indépendamment des livres généalogiques, les associations d'éleveurs tiennent des livres zootechniques ou d'aptitudes, d'après les résultats du contrôle laitier, et de là découle aussi la tenue des livres d'élite, complément logique des Herd-Books.

La pratique du contrôle laitier se heurte en France à quelques difficultés pratiques, notamment la division des exploitations, et l'habitude de laisser le veau têter sa mère. Grâce aux encouragements de l'Etat, néanmoins, il prend une extension chaque jour plus grande.

Espèces ovines et porcines sont encouragées comme les deux autres. Les concours d'animaux sont complétés par des concours de bergeries et de porcheries. Mais le syndicat d'élevage s'est là beaucoup moins développé. Les livres généalogiques sont aussi moins nombreux, il y a néanmoins des

Flock-Books et des Pig-Books pour les races principales de moutons et de porcs.

L'intervention de l'Etat se manifeste encore dans le domaine de la production animale par la sauvegarde de la santé du bétail. La plupart des départements sont dotés d'une direction des services vétérinaires qui, avec la collaboration des vétérinaires praticiens, assure la police sanitaire et prend les mesures prophillactiques désirables pour éviter la propagation des épizooties.

LES RACES FRANÇAISES SUSCEPTIBLES D'INTÉRESSER LE CANADA

Espèce Chevaline.—La race Percheronne est déjà si connue au Canada qu'il doit y avoir bien peu à dire sur son compte. Est-il nécessaire de rappeler que les animaux y appartenant sont vraisemblablement dérivés de l'Arabe? Du cheval de selle dont certaines qualités ont été conservées, on est passé peu à peu au cheval de trait d'aujourd'hui. Le Percheron est un cheval de grande taille, de robe grise, pommelée, ou noire, d'allure souple et légère, doux et intelligent.

Bornons-nous à signaler les points caractéristiques de sa structure: sa tête au chanfrein droit et plat, son encolure ample et rouée, ses hanches longues, sa croupe presque horizontale et légèrement fendue, sa taille: Im. 65 en moyenne (5 pieds anglais).

A côté du gros Percheron, citons le type postier, d'un format moindre et qui ne dépasse pas Im. 60 au garrot.

Les aptitudes du Percheron: vigueur, rusticité, tempérament, ont permis son exportation dans le monde entier, et il semble qu'il fasse excellente figure au Canada.

Le Stud-Book percheron qui fonctionne avec beaucoup de sévérité est fermé depuis plus de 40 ans. Si l'influence de la race se fait sentir sur une grande partie de l'élevage chevalin français, c'est le Perche lui-même, petite région de France, au Nord de la Loire, qui réalise les meilleurs reproducteurs. Le naisseur, petit éleveur, vend généralement, vers l'âge de six mois, après sevrage, les poulains qui se développent chez les herbagers. A 18 mois, suivant leur qualité, les étalons seront ou des sédentaires ou des rouleurs.

Les prix de saillies exigés sont souvent considérables, en rapport avec la valeur exceptionnelle de ces animaux.

La Race Bovine Normande.—Elle peuplait autrefois, sous différents noms, la seule Normandie, c'était la Cautentine, l'Augeronne, la Viroise, etc., groupant en réalité des animaux d'un même type. Sanson rattachait la race Normande à la souche germanique caractérisée par la dolychocéphalie. De fait, si la face est courte le crâne est haut. Un détail bien caractéristique est le "coup de point" entre les yeux. Signalons encore le mufle large, les yeux saillants, les cornes à section circulaire, installées dans un plan horizontal.

Le corps de la Normande, dont l'aptitude est mixte, est ramassé. La poitrine est ample et profonde, la côte est ronde, la croupe est large. Si le cuir est épais, il est par contre très souple. Les muqueuses sont dépigmentées et la robe, caille rouge, caille blonde, est généralement bringée, c'est-à-dire, zébrée de bandes noires plus ou moins régulières.

Il y a cinquante ans que furent groupés les divers types de Normandes, en vue de la création d'un Herd-Book commun organisé par l'Administration préfectorale du Calvados. En 1920, le Livre généalogique fut confié à une association privée. La race est maintenant en pleine expansion et le troupeau normand compte aujourd'hui plus de 3 millions de têtes, le $\frac{1}{5}$ du troupeau français.

Le Herd-Book normand inscrit encore des animaux au titre initial lorsqu'ils en sont jugés dignes. Les mâles doivent être âgés de un an et les femelles avoir mis bas.

Pour assurer les inscriptions au titre de la descendance, l'éleveur doit faire la déclaration de saillie dans les six mois et la déclaration de naissance dans les 15 jours. Un signalement minutieux du veau est donné à cette occasion. Les effectifs inscrits, vivant à l'heure actuelle, sont de 35,000 têtes, dont $\frac{1}{10}$ de mâles, répartis entre 7,000 adhérents. Plus de 140,000 animaux ont figuré au livre généalogique depuis sa fondation.

Le contrôle laitier dont la pratique est mensuelle, est effectué par des syndicats spéciaux exerçant leur action sur 10,000 vaches. Les contrôleurs passent à l'improviste, font les analyses, soit par la méthode Hoyberg (réactif alcalin), soit par la méthode Gerber (réactif acide) et ont le soin de donner des conseils sur l'alimentation du bétail lorsqu'ils remarquent que celle-ci n'est pas convenablement réalisée.

Le contrôle laitier décèle des rendements remarquables, dépassant en 300 jours, 6,000 Kgs de lait et 280 Kgs de beurre, pour des vaches de moins de 5 ans, et atteignant 9,000 Kgs de lait et 400 Kgs de beurre pour des femelles adultes. Les productions oscillant entre 6 et 7,000 litres sont très fréquentes pour une production de beurre de 400 Kgs.

Il était donc logique pour le Herd-Book d'aboutir à la création d'un livre d'élite qui fonctionne aujourd'hui régulièrement depuis juin 1930. Pour inscrire un animal à ce livre, on tient compte de ses origines, de sa conformation, de ses aptitudes beurrières. Une table de pointage est en usage qui prévoit les coefficients suivants:

—	Mâles	Femelles
Pureté de race et robe	4	4
Conformation	4	3
Finesse	2	2
Mamelle	—	1
	10	10

Un total de 80 points est nécessaire à l'inscription.

En outre, le taureau doit avoir dans sa famille six femelles à gros rendement, c'est-à-dire, qui ont donné en 300 jours au moins 180 Kgs de beurre, si elles ne sont pas encore adultes, 200 Kgs si elles le sont. Ces femelles seront ses filles ou ses sœurs de père.

De telles conditions, très sévères, font que le nombre des taureaux inscrits au Livre d'Elite n'est encore que de 5. Les femelles par contre, inscrites lorsqu'elles ont donné les rendements indiqués tout à l'heure, sont au nombre de 500.

En attendant que plus de mâles puissent figurer au Livre d'Elite une formule transitoire est en application, se traduisant par la désignation de taureaux recommandés. Un animal bénéficie de ce titre lorsque, groupant

80 points, il est fils d'une grande beurrière, inscrite elle-même au Livre d'Elite.

En raison de ses remarquables aptitudes à donner du lait, du beurre, de la viande, des veaux renommés, la race normande a pris de l'expansion non seulement en France, mais dans de nombreux pays étrangers. En Europe, l'Italie et l'Espagne s'intéressent à elle. En Amérique, l'Argentine, l'Uruguay, le Chili, le Brésil, le Guatemala viennent fréquemment procéder à des achats. Plus de 200 têtes sont expédiées chaque année. Fait remarquable et qui dénote ses facultés d'adaptation, les Normandes, nées en Amérique du Sud, rivalisent souvent dans les concours avec celles qui viennent d'y être importées.

Les prix modérés pratiqués doivent enfin, semble-t-il, favoriser des courants d'exportation puisque les génisses de 18 mois se vendent 3,000 frs environ, les taureaux de 12 mois, 5 à 6,000 auxquels il suffit d'ajouter 3,000 frs par tête pour tous frais de port et d'assurance.

Les Races à Viande Charollaise et Limousine.—Deux races françaises remarquablement constituées pour la production de la viande sont également capables d'exportation et de fait, très demandées elles aussi dans l'Amérique du Sud.

La CHAROLLAISE, brachycéphale, se rattache au type jurassique. Les animaux de cette race ont la robe uniformément blanche et les muqueuses roses. De grand format, les femelles atteignent 700 Kgs et les mâles souvent plus de 1,000.

La LIMOUSINE, dolychocéphale, est apparentée au type d'Aquitaine. La robe est froment plus ou moins foncé, allant jusqu'au rouge chez les mâles, mais les muqueuses sont dépigmentées. Les femelles pèsent en moyenne 500 Kgs et les mâles 800 et plus.

Si elles sont de formats différents, Charollaise et Limousine sont merveilleusement conformées l'une et l'autre avec un corps très puissant, une culotte accentuée et très descendue. La viande fournie en outre, finement persillée, est de toute première qualité.

Voilà rapidement présenté un schéma de la production animale française. Si certaines de nos races ne peuplent que de petites parties de notre territoire, d'autres, au contraire, ont des facultés suffisantes pour intéresser l'étranger et attirer son attention. Nous souhaitons vivement que le Canada veuille bien les mettre à l'épreuve: il en tirera peut-être les conséquences les plus heureuses en ajoutant une parure au magnifique élevage qu'il a su déjà réaliser.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index of wholesale prices in Canada receded from 72 3 in August to 72.0 in September. Lower sub-indexes were recorded for vegetable products; fibres, textiles and textile products; wood, wood products and paper; iron and its products and non-ferrous metals. Higher indexes were registered for animals and their products; non-metallic minerals and chemicals and allied products. During the first nine months of 1934 the index of wholesale prices averaged 71.7 compared with 66 7 during the same period last year.

Retail Prices.—Retail prices advanced slightly in September, the index rising to 79 0, whereas it was 78 5 in September, 1933. The index of prices of food declined from 69 3 in August to 68 8. Advances were registered in the indexes of fuel, clothing and sundries, but the rise in the clothing index may be due to quarterly revision

Employment.—The employment index (1926 = 100) was 100 0 as at October 1 compared with 98 8 at September 1. Taking employment by industries the indexes at the foregoing dates were manufacturing 94 4 and 94 3, logging 113 4 and 85 6; mining 117 9 and 112 4; communications 81 3 and 82 5; transportation 84.8 and 83.6; construction and maintenance 117 0 and 118 1, services 116 2 and 125 5; trade 120 0 and 117. This is a very satisfactory situation.

Physical Volume of Business.—The physical volume of business showed some contraction in September. The index stood at 99 0 in August which represented a sharp increase. Moreover in the month of September, a thirty-day month, there were five Saturdays and five Sundays which would affect the number of days work and therefore the index. Under these conditions it is not surprising that there was a recession. Industrial production dropped to 97 5. In the manufacturing group food stuffs made a substantial gain. Iron and steel production was well maintained. Indexes of exports and imports were higher. Electric power output showed less than the normal gain. Car loadings showed an increase but it was less than is usually the case at this season of the year. Tobacco releases, production of newsprint, lumber and automobiles were lower than in the previous month Bank debits declined moderately. The construction index was 41.3. Contracts awarded showed a gain, but building permits were lower than in August. Agricultural marketings were lower than in August largely because of a less than normal movement of grain which more than offset an increase in shipments of live stock. Taking the long time view the situation is more reassuring in that the index of the physical volume of business averaged 94 0 in the first nine months of 1934 compared with 77 4 in the same period in 1933.

Agricultural Products.—The index of wholesale prices of Canadian farm products receded from 61 6 in August to 61.3 in September. The average price of No. 1 Manitoba northern wheat was 82.3 cents in September, whereas in August it was 86.0 cents. Wheat prices declined because of a weakened demand in Europe, fairly large supplies from Argentina and the volume of lower grade wheat offered by France at comparatively low prices. The wheat situation shows improvement over a year ago but so far it has not been as great as was anticipated earlier in the crop year. There was a substantial activity in oats at somewhat higher prices and there was an advance in prices of barley but returns for rye and flax were lower. The index of prices of animal products rose from 63.1 to 65.3. This index was affected more by advances in prices of eggs, milk, hides and skins than by the lower price for live animals, particularly steers and lambs.

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1933									
Jan.	63.9	43.6	35.1	57.9	79.1	68.1	62.2	56.1	112.0
Feb.	63.6	43.0	36.0	54.7	78.4	67.0	60.0	76.5	127.6
Mar	64.4	44.7	38.0	56.0	77.8	68.4	62.5	129.0	135.8
April	65.4	46.8	41.1	56.4	78.0	69.8	65.1	104.1	112.7
May	66.9	51.2	46.9	58.4	77.0	76.4	72.7	95.4	110.4
June	67.6	52.6	49.4	57.9	77.0	82.2	79.8	221.9	119.9
July	70.5	60.1	60.8	59.0	77.2	84.1	82.6	221.9	119.9
Aug.	69.4	57.0	54.9	60.5	78.6	89.8	89.5	197.2	114.2
Sept.	68.9	54.7	49.5	63.4	78.5	90.8	90.2	101.1	115.7
Oct.	67.9	51.4	44.6	62.8	77.9	88.2	87.4	70.5	112.7
Nov.	68.7	53.8	46.7	65.8	78.1	85.5	83.9	41.8	111.1
Dec.	69.0	53.3	45.3	66.6	78.4	86.2	85.1	30.7	107.6
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1931, p. 15

2. Wholesale prices of Canadian products of farm origin only See Prices and Price Indexes 1913-1931, p. 33, and Monthly Mimeographs 1933 and 1934.

3 Wholesale prices of grains, fruits and vegetables

4. Wholesale prices of Animals and Animal Products

5. Including foods, rents, fuel, clothing and sundries. See Prices and Price Indexes 1913-1928, pp 181-185, 290-293. 1926 = 100.

Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeographs 1933-1934.

6. Monthly Review of Business Statistics, p. 8 and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

External Trade.—The value of domestic exports from Canada during the six months ending September was 317 million dollars compared with 265 million during the same period of 1933. The value of exports for the twelve months ending September was 631 million dollars whereas in the same period ending September in 1933 it was 505 million. The value of imports during the six months periods referred to above was 264 million as against 200 million and for the twelve months ending September this year the value was 497 million, whereas in the preceding twelve month period it was 385 million. This improvement in external trade is a hopeful sign.

Drought in United States.—*The Agricultural Situation* published by the Bureau of Agricultural Economics at Washington, D.C., in the issue of October 1st, in part refers to the effects of drought as follows:

"The lasting consequences of the drought, as long foreseen, are now coming to rest upon the live stock industries. With corn and oats about half an average crop, and with hay much the smallest crop in 15 years, the problem is to find means for carrying foundation stock after the emergency reduction of the flocks and herds. This curtailment, already under way, will go on probably all winter. It means apparently that the country will begin the year with 8 to 10 million fewer cattle than it had a year previous. It means probably the smallest supply of hogs this winter in 20 years and very likely still smaller supplies a year from this winter".

The index of farm prices in United States (August 1909--July 1914 = 100) advanced from 96 in August to 102 in September. Among the sub-indexes that for grains rose from 106 to 112. Cotton and cotton seed advanced from 107 to 110. Fruits fell from 101 to 93; truck crops rose from 108 to 110, dairy products from 97 to 99, chickens and eggs from 86 to 104; meat animals advanced from 68 to 82. The index of the ratio of prices received to prices paid rose from 77 to 81, the highest thus far during the year.

A Levy on Bacon Imports.—Uneven supplies of bacon and consequently more or less unsatisfactory prices for English bacon has caused criticism of the pigs marketing scheme and the bacon marketing scheme among farmers in some sections of Great Britain and it is now proposed that the government should make a levy on imports of bacon. The government has not indicated what action will be taken but it is an interesting development.

LA SITUATION ÉCONOMIQUE

PRÉPARÉE PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE DU MINISTÈRE DE L'AGRICULTURE À OTTAWA, D'APRÈS DES DONNÉES BASIQUES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

De 72.3 qu'il était en août l'indice des prix de gros au Canada a rétrogradé à 72.0 en septembre. Il y a eu un recul également dans les sous-indices des produits végétaux; des fibres, des textiles et des produits textiles; du bois, des produits du bois et du papier; du fer et ses produits et des métaux non ferreux. Il y a eu, par contre, un relèvement de l'indice pour les animaux et leurs produits; les minéraux non métalliques et les produits chimiques et similaires. Pendant les neuf premiers mois de 1934 l'indice des prix de gros était en moyenne de 71.7 contre 66 7 pendant la même période l'année dernière.

Prix du détail.—Les prix du détail se sont relevés légèrement en septembre, l'indice montant à 79 0, tandis qu'il était à 78 5 en septembre 1933. L'indice des prix des denrées alimentaires, qui était à 69 3 en août, est tombé à 68.8. Des hausses ont été enregistrées dans les indices du combustible, des vêtements et d'autres produits, mais le relèvement des indices des vêtements peut être dû à la revision trimestrielle.

Embauchage.—L'indice de l'embauchage était à 100 0 au 1er octobre contre 98·8 au 1er septembre (1926 = 100). Les indices des différentes industries en ce qui concerne l'embauchage étaient aux points suivants aux dates qui précèdent: manufacture, 94.4 et 94.3; billots 113.4 et 85.6; mines 117.9 et 112.4; communications 81 3 et 82 5; transports 84 8 et 83 6; construction et entretien 117.0 et 118.1; services 116 2 et 125 5; commerce 120 0 et 117. C'est là une situation très satisfaisante.

Volume physique des affaires.—Le volume physique des affaires a un peu diminué en septembre. L'indice était à 99 0 en août ce qui représentait une forte augmentation. En outre, il y avait eu, en septembre. qui est un mois de trente jours, cinq samedis et cinq dimanches, ce qui, naturellement, affecte le nombre des jours de travail et, par conséquent, l'indice. Il n'est pas surprenant qu'il y ait eu une baisse dans ces conditions. La production industrielle est tombée à 97 5. Dans le groupe des produits manufacturés, les denrées alimentaires ont fait un gain considérable. La production du fer et de l'acier s'est bien maintenue. Les indices des exportations et des importations se sont relevés. La production d'énergie électrique n'a pas accusé le gain normal habituel. Les chargements de wagons étaient en augmentation mais cette augmentation était inférieure à celle que l'on enregistre ordinairement à cette saison de l'année. Les livraisons de tabac, la production de papier à journal, de bois et d'automobiles, étaient inférieures à celles du mois précédent. Les débits de banques ont modérément diminué. L'indice du bâtiment était à 41 3. Le nombre de contrats était en augmentation mais les permis de construction étaient plus faibles qu'en août. Les ventes agricoles étaient inférieures à celles d'août, principalement à cause des expéditions de grain qui étaient inférieures à la normale, contrecarrant ainsi l'augmentation qui s'est produite dans les expéditions de bestiaux. Envisagée au point de vue du temps, la situation est plus rassurante en ce sens que l'indice du volume physique des affaires accusait une moyenne de 94 0 pendant les neuf premiers mois de 1934 contre 77.4 pour la même période en 1933.

Produits agricoles.—L'indice des prix de gros des produits agricoles canadiens qui était à 61.6 en août est tombé à 61.3 en septembre. Le prix moyen du blé du Nord Manitoba No. 1 était à 82 3c. en septembre tandis qu'il était à 86.0c. en août. Les prix du blé ont baissé parce que la demande européenne s'est ralentie, que l'Argentine a mis sur le marché d'assez gros approvisionnements et que la France a offert à prix relativement bas des quantités de blé de catégorie inférieure. La situation du blé est certainement meilleure que l'année dernière mais la demande n'a pas été

aussi forte que l'on espérait au commencement de l'année de récolte. Le commerce de l'avoine a fait preuve d'une activité considérable, à prix un peu plus élevés, et les prix de l'orge ont monté tandis que les recettes pour le seigle et le lin diminuaient. L'indice des prix des produits animaux s'est élevé de 63.1 à 65 3. Cet indice a été plus affecté par les hausses de prix des oeufs, du lait, des cuirs et des peaux que par la baisse de prix pour les animaux en vie, spécialement les boeufs et les agneaux.

Commerce extérieur.—La valeur des exportations domestiques du Canada pendant les six mois finissant en septembre a été de 317 millions de dollars contre 265 millions pendant la même période en 1933. La valeur des exportations pendant les douze mois finissant en septembre a été de 631 millions de dollars contre 505 millions pendant la même période finissant en septembre 1933. La valeur des importations pendant les périodes de six mois mentionnées ci-dessus a été de 264 millions contre 200 millions et pendant les douze mois finissant en septembre cette année, la valeur a été de 497 millions, tandis que pendant les douze mois précédents elle avait été de 385 millions. Cette amélioration du commerce extérieur est un symptôme encourageant.

La sécheresse aux Etats-Unis.—***La situation agricole*** publiée par le Bureau de l'économie agricole de Washington, D.C. traite des effets de la sécherese dans les termes suivants (Numéro d'octobre).

"Les conséquences durables de la sécheresse, depuis longtemps prévues, affectent maintenant les industries animales. Les récoltes de mais et d'avoine n'atteignent guère que la moitié de la récolte ordinaire, la récolte de foin est la plus faible que l'on ait rentrée depuis 15 ans, et le grand problème est de trouver un moyen de faire vivre les bêtes, même après la réduction que l'on a faite dans l'effectif des troupeaux. Cette réduction, déjà entreprise, durera probablement tout l'hiver, et il est probable qu'il y aura dans le pays au commencement de l'année, de 8 à 10 millions de bovins de moins que l'année précédente. La population porcine de cet hiver sera sans doute la plus faible que l'on ait vue depuis 20 ans et elle sera tout probablement encore réduite un an plus tard."

L'indice des prix de ferme aux Etats-Unis (août 1909-juillet 1914 = 100) qui était à 96 en août est passé à 102 en septembre. Parmi les sous-indices, celui des grains s'est élevé de 106 à 112. Le coton et la graine de coton ont passé de 107 à 110. Les fruits sont tombés de 101 à 93; les récoltes maraichères se sont élevées de 108 à 110, les produits laitiers de 97 à 99, les poulets et les oeufs de 86 à 104; et les animaux à viande de 68 à 82. L'indice de la relation entre les prix reçus et les prix payés s'est élevé de 77 à 81, c'est l'indice le plus élevé que l'on ait encore enregistré cette année.

Une levée sur les importations de bacon.—L'irrégularité des approvisionnements de bacon occasionnant des prix plus ou moins peu satisfaisants pour le bacon anglais a provoqué une critique du plan de vente des porcs et du plan de vente du bacon parmi les cultivateurs de certaines parties de la Grande-Bretagne, et l'on propose maintenant que le gouvernement impose une taxe sur les importations de bacon. Le gouvernement n'a pas encore indiqué les mesures qu'il prendra mais le développement noté est intéressant.

AVIS POUR LES LECTEURS FRANCAIS

Nos lecteurs de langue française ne trouveront pas dans ce numéro, les résumés habituels des articles anglais. Ces articles et les rapports de comité sont si longs qu'il aurait été très difficile d'en faire une analyse. D'ailleurs, ces travaux et ces rapports constituent par eux-mêmes un résumé de programmes, et comme ils sont à peu près entièrement dépourvus de termes techniques, la lecture dans la forme originale ne devrait présenter aucune difficulté. Les lecteurs qui désireraient avoir des renseignements détaillés, en français, sur les sujets présentés par les Drs. Wickware, Rosell, Conklin et Parnell sont priés de se mettre directement en communication avec ces auteurs. Le travail par M. Thiéry, de Dijon, France, a été présenté à la convention annuelle de la Société des Agronomes Canadiens, au Collège Macdonald, le 27 juin, 1934. La visite de M. Thiéry au Canada a pu se faire grâce à l'obligeance du Gouvernement français et du Gouvernement de la Province de Québec.

ANNUAL MEETING OF THE CANADIAN SOCIETY OF ANIMAL PRODUCTION—EASTERN SECTION

The fifth annual meeting of the Canadian Society of Animal Production—Eastern Section was held at Macdonald College, P.Q., under the chairmanship of the President, Prof. J. C. Steckley of the Ontario Agricultural College, Guelph. The papers and main committee reports presented at this session were assembled by the Secretary of the Society, Mr. E. B. Fraser of the Animal Husbandry Division, Central Experimental Farm, Ottawa. The following officers were elected for the year 1934-35:

President—Mr. C. F. Bailey, Dominion Experimental Farm, Fredericton, N.B.

Vice-President—Prof. A. R. Ness, Macdonald College, P.Q.

Secretary-Treasurer—Mr. E. B. Fraser, Central Experimental Farm, Ottawa, Ont.

Maritime Director—Mr. W. W. Baird, Dominion Experimental Farm, Nappan, N.S.

Quebec Director—Mr. S. J. Chagnon, Provincial Nursery, Deschambault, P.Q.

Ontario Director—Prof. R. G. Knox, Ontario Agricultural College, Guelph, Ont.

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SOIL TEMPERATURES AT WINNIPEG, MANITOBA

WALLACE A. THOMSON[1]

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Following the installation of a set of eight electrical resistance thermometers, soil temperature readings have been taken at various depths weekly since October, 1929. These thermometers were installed under the supervision of Mr. J. Patterson, Director of the Meteorological Service of Canada, and the late Professor S. C. Lee, and records have been kept by the Physics Department of the Manitoba Agricultural College. The thermometers are located in a grass plot about one hundred feet south of the Physics building at the following depths: Surface, 4 inches, 10 inches, 20 inches, 40 inches, 66 inches, 9 feet, 15 feet. A hole was made to a depth of about eight feet, large enough to allow a person to make small auger holes in the walls of the larger hole in such manner as was necessary to reach the various depths. The thermometers, protected by a waterproof covering, were placed in these auger holes, and the soil replaced in as nearly as possible the same condition as before removal. The wires from these thermometers, together with the compensating wires, were brought into the building underground in a waterproof tube. With the careful replacing and tamping of the soil, and the fact that the records published in this paper were taken at least four years after the installation it is probable that the condition of the soil in which these temperatures were taken was very similar to its condition before it was disturbed. The resistance of each thermometer was measured by the bridge method and these resistances converted to degrees Fahrenheit by reference to a previously prepared calibration chart.

PREVIOUS WORK

Callendar and McLeod (*1*), (*2*), used platinum wire resistance thermometers at depths similar to those in this investigation with the omission of the 15-foot depth, and the surface thermometer, giving special attention to the conditions which effect soil temperature. Harrington (4) reported a similar investigation conducted at Saskatoon, using eight thermometers at depths varying integrally from 1 to 8 feet and having the temperatures automatically recorded.

Smith (6) made a study of the interrelations between the temperature of the surface soil and the atmosphere immediately above it and found that by the use of an enlarged bulb thermometer the temperature of the surface soil was lower than that of the air in contact with it just before sunrise on calm nights.

[1] Formerly Lecturer in Physics, Manitoba Agricultural College, Winnipeg, Manitoba.

Kimball, Ruhnke and Glover (*5*) report very considerable lag in the response of soil to air temperature changes and also that the time lag increases with depth. In 4 inches of soil there was a lag of 6 to 7 hours and at 12 inches a lag of 10 hours. They also found the maximum temperatures to be in descending order in all cases: Air; soil at 4 inches, 12 inches, 24 inches, and that no soil approached the air maximum temperature within 10° F. or came within 20° F. of the minimum.

SOIL TYPE

The nature of the soil in which these thermometers were exposed will necessarily have considerable bearing upon the records obtained. Of special importance is its moisture holding capacity, since the thermal conductivity would depend to a considerable extent on the moisture content.

The following description of the soil in which the thermometers were placed has been kindly submitted by Professor J. H. Ellis, Soils Division, Agronomy Department, Manitoba Agricultural College:

> "The clay deposits of the Lake Agassiz basin, which extend throughout the level topography of the Winnipeg area, have been described by Wallace and Maynard (*7*). At the point where the thermometers are located five distinct deposits occur.
>
> 1. The surface deposit of lacustrine clay extends to the lower fourth and the upper part of the fifth foot. This has been modified at the surface by man and contains considerable concretionary lime carbonate from soil weathering in the lower portion.
> 2. This clay sediment is underlaid from the fifth to the seventh foot by a deposit of marly, very fine sandy clay, which is more or less laminated.
> 3. Below this second deposit deep lacustrine fine clay occurs.
> 4. In the ninth foot a band of yellowish brown iron stained silt extends horizontally from four to six inches in depth, which was deposited during a period of temporarily shallow water.
> 5. Below this band the deposit consists of the closely packed, grey and brownish grey, laminated varve clays deposited in the deep waters of Lake Agassiz. This deposit extends considerably below the depth of the lowest thermometers.
>
> The soil, which has developed on the surface deposit may be described as a slightly degraded clay chernozem. It has developed under woodland invasion of prairie from which the trees were removed in 1911-12 and seeded to lawn grass about 1915. The chief soil characteristics may be noted as follows:

A horizon	0″ – 8″	Dark, granular clay and sod roots.
B1 horizon	8″ – 18″	Black tough compact clay with weakly fragmental to cloddy structure.
B2 horizon	18″ +	Dark stained brownish grey clay with feebly developed fragmental to granular structure, irregularly tongued and dark stained from above.
Cl horizon	3′ – 4′	Grey-brown clay moderately friable with numerous lime concretions."

A more detailed description and the peculiar tongued condition which occurs in the soils of the Agassiz clays is given by Ellis and Shafer (*3*).

RESULTS

The taking of observations was begun October 21, 1929, and they have been taken each Monday at 9 a.m. since that time with the exception of a period of eleven weeks beginning July 7, 1930. Readings taken daily

would have been more valuable for the upper thermometers, especially during the summer, but owing to the time involved sufficient help was not available. It was found that during the winter when the ground was snow covered, the variations in these upper thermometers were slight even when the air temperature variations were extreme. For short periods on certain occasions during the summer months readings were taken daily and it was found that the surface thermometer, which is covered only with sufficient soil to shut off the direct rays of the sun, responded to changes of air temperature with a lag of about one hour, reaching a temperature approaching 80° F. when the air temperature was near 100° F. On these occasions the 4-inch thermometer lagged behind the surface about three hours with less extreme variations. At a depth of 40 inches the effect of extreme variations in air temperature was scarcely noticeable.

The temperature variation curves for the various depths shown in Figure 1 represent the average of three years' results, *i.e.*, 1931-32-33.

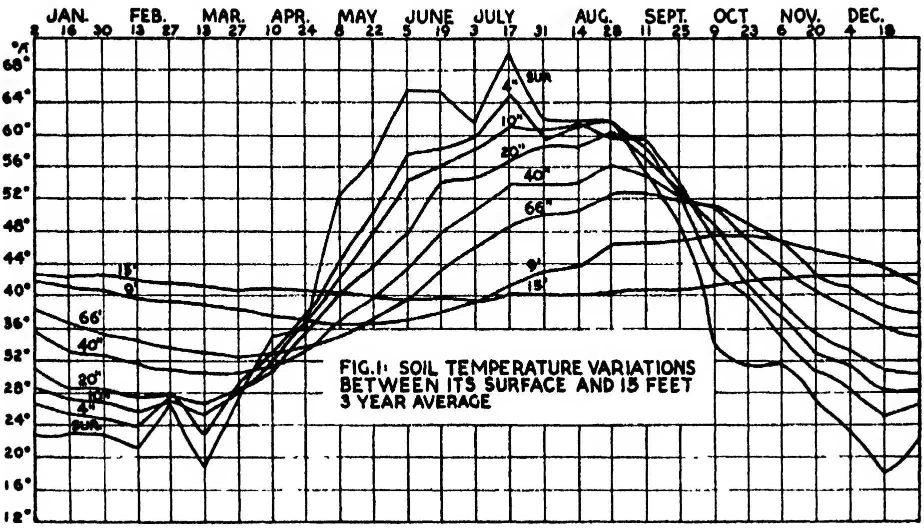

FIGURE 1. Soil temperature variations between its surface and 15 feet; 3 year average.

The curves for each individual year show so little variation in the more important details that the average alone has been included in this report and mention will be made of any point in which a noticeable difference occurred.

What is generally called the "overturn" in soil temperatures is well illustrated in Figure 1. During the winter months the soil temperature increases as the depth increases, the reverse being true during the summer. This overturn during the three years represented by this chart began on March 27th and was completed to a depth of 66 inches by April 27th, 9 feet by May 19th, and 15 feet July 3rd, fourteen weeks being required for the complete overturn. The fall overturn started on August 28th and was complete to a depth of 66 inches October 3rd, 9 feet November 3rd and 15 feet December 24th, requiring a total time of nearly seventeen

weeks. The temperature range for the entire group of curves shows one minimum on April 27th and another on October 3rd. Harrington (4) found the corresponding dates at Saskatoon for the year 1923 to be April 16th and October 10th and considered these dates as the days on which the overturn took place.

Probably the most noticeable feature about this set of curves is the decrease in temperature variations as the depth increases, the two upper thermometers varying rapidly with changes in air temperature while the 15-foot thermometer shows a variation of less than four degrees over the entire year. It will also be noticed that the four thermometers in the upper 20 inches reached their lowest temperature on March 13th, while the lowest temperature at 40 inches was registered on March 20th, and 66 inches on March 27th, at 9 feet on May 8th, and at 15 feet on July 3rd, which is only two weeks previous to the date on which the top two thermometers registered their highest temperature. An examination of Tables 1 and 2, which give the minimum and maximum temperatures recorded

TABLE 1.—LOWEST TEMPERATURES RECORDED ON SOIL THERMOMETERS

Depth	1929-30		1930-31		1931-32		1932-33		1933-34	
	Temp., °F.	Date	Temp., °F.	Date	Temp., °F	Date	Temp., °F.	Date	Temp., °F.	Date
Sur.	19 36	Jan. 20	23 25	Dec. 1	5 44	Mar. 7	12 73	Mar 20	5 21	Mar 26
4 in.	20 55	Jan. 27	28 62	Mar. 16	19 12	Mar 7	19 40	Feb. 13	18 12	Jan. 22
10 in.	22 63	Jan. 27	29.68	Mar. 23	19 62	Mar. 14	22 20	Feb. 20	23 85	Mar. 26
20 in.	25 03	Feb. 3	29 76	Mar. 23	23 50	Mar. 14	23 50	Feb. 20	27 47	Mar. 26
40 in.	29 86	Feb. 17	32 02	Mar 23	29 08	Mar 28	27 93	Feb. 20	28 95	Feb. 19
66 in.	31 58	Mar. 24	33 18	Mar. 23	30 85	April 4	31 24	Mar. 6 Mar. 27	31 06	April 9
9 ft.	35 03	May 12	37 24	April 20	35 48	May 23	35 45	May 1	34 94	April 30
15 ft.	39 30	June 23	39 91	July 13	39 02	Aug. 8	38 52	June 26		

TABLE 2.—HIGHEST TEMPERATURES RECORDED ON SOIL THERMOMETERS

Depth	1930		1931		1932		1933	
	Temp., °F.	Date	Temp., °F.	Date	Temp., °F.	Date	Temp., °F.	Date
Sur.	—	—	76 96	June 29	70 19	June 20	81 10	Aug. 7
4 in.	—	—	68.27	June 29	66 61	July 18	69 23	Sept. 4
10 in.	—	—	63 88	June 29	64.23	Aug. 15	62 44	Aug. 7
20 in.	—	—	60 76	Aug. 31	60 37	Aug. 29	60.57	Aug. 28
40 in.	—	—	56.27	Aug. 31	55.72	Sept. 5	57.02	Aug. 28
66 in.	50 61	Sept. 29	54.83	Aug. 31	52.42	Sept. 19	53 37	Aug. 28
9 ft.	46.51	Oct. 6	48 80	Aug. 31	47.59	Oct. 10	47 85	Oct. 9
15 ft.	43 57	Dec. 1	43 51	Dec. 21	42 96	Nov. 14	42.90	Jan. 1/34

annually by each thermometer with the date of occurrence, shows that the lag at a depth of 15 feet is very nearly six months, this thermometer reaching its lowest temperature about the second week in July and its highest temperature on the average about December 15th. The lag at 9 feet is about three months, the highest temperature being reached at

this depth early in October, and the lowest temperature about the middle of May.

Since the temperature range at a depth of 9 feet is about 14° F. and at 15 feet is about 4° F. it is quite probable that at a depth of about 20 feet the temperature of the soil would remain practically constant and beyond this depth the extreme variations which occur in air temperatures in this country—as much as 140° F. between a hot day in summer and a cold day in winter—would have no effect.

The effect of a snow covering on the control of soil temperatures has become evident at many times during this investigation. In Figure 1 the absence of rapid variations in temperature by the upper thermometers during the months of December, January and February as compared with the summer months is very noticeable. A week of mild weather late in February 1932 completely removed the snow cover from the plot in which the thermometers were exposed. Then a drop in air temperatures caused the surface thermometer to register 5.44° F. on March 7th and 6.34° F. March 14th, which was more than 6° F. lower than at any other time during the winter and about 15° F. below the winter average. The air temperature during that week showed a minimum of −18° F. on March 6th and an average minimum for ten days of −12° F., yet there were several days during January and February when the air temperature went below −30° F. with a surface soil temperature of about +20° F.

In Figure 2 the temperatures registered by the surface and 4-inch thermometers at this time are shown graphically and the drop in temperature early in March following the removal of the snow cover is very apparent. This figure shows also another depression, particularly in the surface temperature, on December 21st caused also by the absence of any snow cover. The same thing occurred in March 1933 when the surface thermometer registered a low for the winter of 12.73° F. on March 20th after the protecting snow cover had been removed, this temperature again being several degrees lower than at any other time during the winter with a corresponding air temperature of only 0° F. This would add support to the common belief that the winter killing of plants is very apt to be caused by a too early removal of the snow cover.

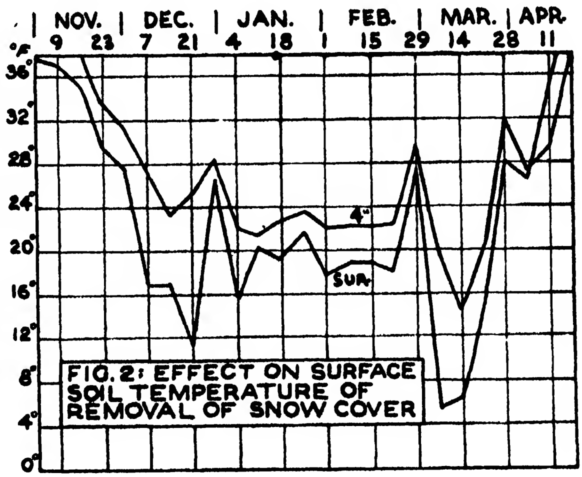

FIGURE 2. Effect on surface soil temperature of removal of snow cover.

Figure 3 shows the date at which each thermometer first recorded a temperature below 32° F. and also shows the rate at which the frost zone

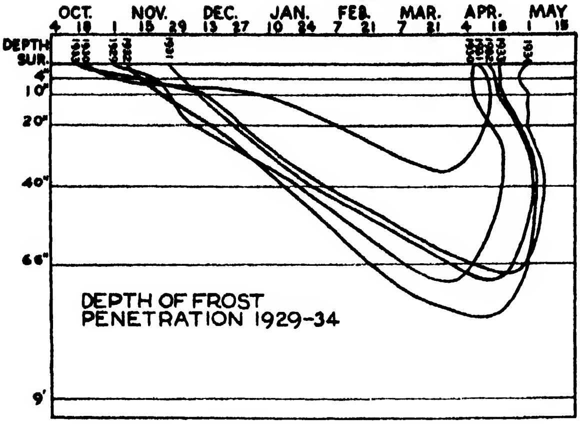

Figure 3. Depth of frost penetration 1929-34.

penetrated the soil in the early winter, the depth to which it penetrated, and the rate at which the soil returned to a frost-free condition in the spring. It will be noticed that the soil became frozen from the surface gradually downward usually starting early in November, while in the spring the removal of frost appears to start at the surface and at the lower frost level at about the same time, leaving the last sign of frozen soil late in April or early in May at about the four foot level.

Considerable variation is to be found in both the rate of penetration of frost and the depth to which it penetrates. In 1930 the surface thermometer first showed a temperature below freezing on October 20th and did not rise again above 32° F. until April 6th, 1931. A heavy fall of snow late in October prevented a rapid movement downward of the frost zone, and an unusually mild winter with temperatures which, however, did not remove the snow covering, prevented the frost from reaching a depth greater than about 36 inches. The 40-inch thermometer recorded a low for the winter of 32.02° F. on March 23rd. In 1932 the surface thermometer recorded temperatures below freezing continually from October 31st to April 17th, 1933. The winter was severe, resulting in an almost uniform movement downward of the frost zone at a rate of about 20 inches a month. The 66-inch thermometer recorded a temperature below freezing continually between February 20th and May 1st. The lowest temperature reached at the 9 foot level during this time was 35.45° F. on May 1st, while the 66-inch thermometer was fairly constant between 31 3° F. and 31.7° F. It should be clearly understood that the actual depths to which the frost penetrated could only be estimated from the temperatures recorded by the thermometers situated immediately above and below the lower frost level, but the curves given in Figure 3 should represent with a fair degree of accuracy the frost conditions as they actually existed.

Figure 4 illustrates the comparison between the average air temperature and the average soil temperature at the various depths, April to September, October to March, and the yearly average. Each curve represents an average of all readings taken during the period indicated for three consecutive years, the air temperatures being taken within 200 feet of the location of the soil thermometers, and in a standard instrument shelter. From April to September the average air temperature was 58.4° F., while the average temperature at the surface of the soil was 56.1° F., a difference of only 2.3° F., but as the depth increases this difference rapidly increases until at the 9 foot depth it is 17.81° F. and at

15 feet it is 18.15° F. During the winter season the average air temperature is 15.61° F. and that of the surface soil 25.34° F., a difference of 9.73° F. The winter season difference at 9 feet is 27.09° F. and at 15 feet it is 26.44° F.

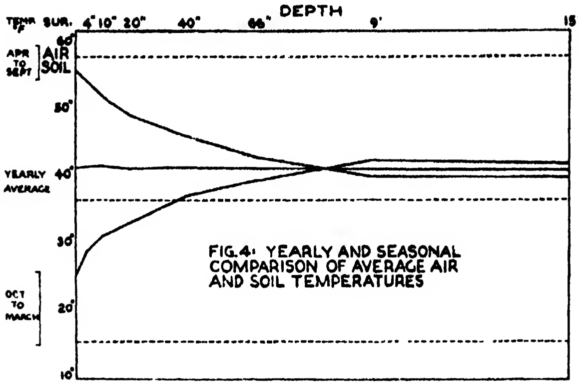

FIGURE 4. Yearly and seasonal comparison of average air and soil temperatures.

When the average temperature at each depth for this three year period was found the result was noteworthy in that all depths were found to have very nearly the same average temperature. The 10-inch thermometer was high with an average of 41 97° F. and the 15-foot thermometer was low with an average of 41 09° F., the average of all depths being 41 58° F. Comparing this with the average air temperature for the same three year period of 36.92° F. it is seen that the average temperature of the soil between the surface and the 15-feet depth is 4 66° F. higher than the average air temperature four feet above the surface. This difference may be partly due to the prevention by the snow cover of a rapid loss of heat during the winter months and to the latent heat of fusion of ice, but is probably due largely to the outward flow of heat from the interior of the earth.

It will be noticed that the two seasonal soil temperature curves in Figure 4 cross each other on the curve representing the yearly average at a point corresponding to a depth of 92 inches, separating again beyond that point and approaching the average again as the depth increases. Thus we find, that the soil temperatures from the surface to a depth of 92 inches are higher than the yearly average in summer and lower in winter, while below this depth the soil temperatures are on the average lower during the summer season than the yearly average and higher during the winter season. At that depth of 92 inches the winter season average is the same as that for the summer season.

DISCUSSION

The importance of soil temperature to the agriculturist is evident in the spring of the year when one considers this factor responsible for quick germination of seed and rapid early growth upon which the ultimate success of the crop may so largely depend. Wheat may be sown on adjoining fields on dates differing as much as two or even three weeks in certain years and be harvested at the same time due to the low temperature of the soil in early spring and consequent slow germination and early growth. When time is so often such an important factor in the production of wheat in Western Canada any effort made by the grower to hasten higher soil temperatures in the spring would be of some importance. Man has no control over the meteorological elements which are directly responsible for soil temperatures, but he can at least in some cases encourage the

accumulation of snow in winter and provide for more adequate drainage of surplus water in the early spring.

The time at which cutworm and grasshopper activity begins each spring is determined by soil temperature, and upon this, in turn, will depend the possibility of nature reducing their activities by a period of cold and unfavorable weather. In 1933, soil temperatures were slow to rise with the result that grasshoppers were not seen above the ground in most parts of Saskatchewan until early in June with nothing but summer weather to aid them in their campaign of destruction. In 1934 an early rise in soil temperatures has brought the first grasshoppers above the ground in the same district on May 8th, giving, it would seem, a much greater possibility of a reduction in numbers by unfavorable weather.

ACKNOWLEDGMENTS

The writer wishes to acknowledge with thanks the assistance given by Mr. Charles Gibson, by whom the readings have been taken.

REFERENCE

1. CALLENDAR, H. L. and C. H. McLEOD. Observations of soil temperatures with electrical resistance thermometers. Trans. Royal Society of Canada, 1896, Sec. III : 109.
2. ——————. ——————. Observations of soil temperatures with electrical resistance thermometers. Trans. Royal Society of Canada, 1897, Sec. III : 31.
3. ELLIS, J. H. and W SHAFER. The nitrogen content of Red River Valley soils. Sci. Agr. *9* : 231. 1928.
4. HARRINGTON, E. L. Soil temperatures in Saskatchewan. Soil Sci. *25* : 183. 1928.
5. KIMBALL, D. A., G. N. RUHNKE and M. P. GLOVER. A comparison of temperatures in air and at various depths in a light sandy soil in Southern Ontario. Sci. Agr. *14* 353-359. 1934.
6. SMITH, ALFRED. A contribution to the study of interrelations between the temperature of the soil and of the atmosphere and a new type of thermometer for such study. Soil Sci. *22* : 447. 1926.
7. WALLACE, R. S. and J. E. MAYNARD. The clays of Lake Agassiz Basin. Trans. Royal Society of Canada. 1924. Sec. IV . 9-30.

Résumé

Température du sol à Winnipeg, Manitoba. Wallace A. Thomson, Pense, Saskatchewan.

Huit thermomètres à résistance électrique ont été installés dans une parcelle herbeuse aux profondeurs suivantes: à la surface, 4 pouces, 10 pouces, 20 pouces, 40 pouces, 66 pouces, 9 pieds, 15 pieds, et des lectures ont été prises toutes les semaines au moyen de la méthode Bridge. Le "roulement" des températures, pendant une période de trois ans, s'est commencé le 27 mars et terminé à une profondeur de 66 pouces le 27 avril, de 9 pieds le 19 mai et de 15 pieds le 3 juillet; il a fallu quatorze semaines pour le roulement complet. Le roulement d'automne s'est commencé le 28 août et terminé le 24 décembre, exigeant ainsi dix-sept semaines. Les deux thermomètres les plus près de la surface ont varié rapidement suivant les changements qui se produisaient dans la température de l'air, tandis que la variation enregistrée par le thermomètre placé à 15 pieds n'a pas atteint 4° F. de toute l'année. Le maximum a été atteint en décembre et le minimum au commencement de juillet. Ces variations ont été modifiées considérablement par la couverture de neige, les thermo-

mètres supérieurs enregistrant leur plus basse température aux premiers jours du printemps, après l'enlèvement de la neige. A partir du commencement de novembre généralement, le sol gelait à la surface et la gelée descendait graduellement dans les profondeurs; au printemps la disparition de la gelée commençait à la surface et au niveau le plus bas à peu près vers la même époque, laissant la dernière trace de terre gelée au commencement de mai au niveau de quatre pieds environ. La profondeur de pénétration de la gelée variait beaucoup suivant la nature de la couverture de neige et la rigueur de l'hiver. La profondeur atteinte n'a été que de 36 pouces en 1930-31 tandis qu'elle dépassait 6 pieds en 1932-33. Pendant la saison d'hiver, d'octobre à mars inclusivement, la température moyenne de l'air prise dans un abri régulier pour instruments météorologiques, était de 15.6° F. et celle du sol de surface de 25.34° F. A 9 pieds la température d'hiver était de 42 70° F., et à 15 pieds de 42.05° F.

La température moyenne pendant toute la série de trois ans a été à peu près la même à toutes les profondeurs oscillant seulement entre 41 09° F. et 41.97° F. Pendant la même période de trois ans la température moyenne de l'air a été de 36 92°F. On voit donc que la température moyenne des 15 premiers pieds de sol est de 4.66° F. plus élevée que la température moyenne de l'air prise à quatre pieds de la surface. La température du sol, à partir de la surface jusqu'à une profondeur de 92 pouces, était plus élevée en été et plus basse en hiver que la température moyenne annuelle pour toutes les profondeurs. C'est l'inverse qui s'est produit pour la température au-dessous de cette profondeur tandis qu'à une profondeur de 92 pouces les moyennes pour l'été et l'hiver sont les mêmes.

THE EVALUATION OF THE GERMICIDAL POTENCY OF CHLORINE COMPOUNDS. II. CHLORAMINE-T PRODUCTS

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A number of products in which chlorine in the form of chloramine-T (sodium paratoluene-sulphonchloramide) is the active ingredient are being offered for the sterilization of equipment, etc., in dairy and food plants. This type of sterilizing agent differs from hypochlorite principally in being (1) more stable, especially in the presence of organic matter, and (2) much slower in action. On this latter point the literature indicates considerable disagreement. Dakin, Cohen and Kenyon (*4*) believed its antiseptic action to be four times as great as that of hypochlorite. Tilley (*20*), employing the Rideal-Walker method, reported a significantly higher phenol coefficient for chloramine-T than for sodium hypochlorite against *Staph. aureus*. Myers and Johnson (*16*), using the F.D.A.[2] method, found a chloramine-T product (Santamine) more effective than five hypochlorites of medium to high alkalinity, although inferior to six less alkaline hypochlorites. In a previous paper Johns (*10*), using the F.D.A. method, reported similar results with a chloramine-T product (Wyandotte Sterilizer) containing a large percentage of sodium bicarbonate as "filler." On the other hand, a number of workers (*1, 2, 5, 7, 8, 9, 11, 13, 15, 17, 18*) have reported chloramine-T solutions as being distinctly inferior to hypochlorites in germicidal speed.

The explanation for these apparently contradictory findings would appear to lie in the property of chloramine-T solutions mentioned above, *i.e.* their much greater stability in the presence of organic matter. Where large quantities of organic matter are added to the test solution as in the usual phenol coefficient methods, the depressive influence upon the germicidal activity of chloramine-T is very much less than in the case of hypochlorites. This is well illustrated by the findings of Myers and Johnson (*16*) and Johns (*10*). The former required a 25% greater concentration of chloramine-T to destroy *Staph. aureus* in bottle rinsing tests than in the F.D.A. technique, while with four hypochlorite products the concentration required in the bottle rinsing tests was from one-fifth to one-tenth of that required in the F.D.A. method. Johns found that where the broth culture inoculum for the F.D.A. method was diluted 1/100 the chloramine-T product appeared distinctly inferior to the six hypochlorite solutions tested concurrently.

Where chlorine solutions are to be used in the presence of considerable amounts of organic matter, such as in wound treatments, etc , it is obviously necessary to employ a testing method in which considerable quantities of organic matter are introduced into the disinfectant solution along with the test organism. On the other hand, where they are intended for use in destroying bacterial growths on the surfaces of *clean* equipment, utensils, etc., the usual phenol coefficient methods give an erroneous impression of the relative germicidal efficiency of the two types of chlorine compounds,

[1] Assistant Agricultural Bacteriologist.
[2] The method employed by the Food and Drug Administration of the U.S. Department of Agriculture.

and it is necessary to employ testing methods in which the concentration of organic matter is kept at a more appropriate level.

The first paper of this series (*10*) dealt principally with the evaluation of the germicidal potency of hypochlorite products. A number of methods were tried out and their suitability reported upon. One of these, the Burri slant method, was found to be reasonably satisfactory and much freer from "skips" and "misses" than the methods previously employed. Subsequently a simple indicator test for pH and a biological testing method referred to as the "glass slide method" were developed and tested out. It was decided to try out these methods on a smaller series of chloramine-T products, and the results of these tests are reported below.

EXPERIMENTAL

In all the studies reported in this paper, a standardized suspension of *Staphylococcus aureus* (U.S.D.A. No. 209) as used by Myers and Johnson (*16*) was employed. The growth on a Bacto nutrient agar slant (24 hours at 37° C.) was suspended in sterile tap water, filtered through a No. 41 Whatman paper and standardized against a Fuller's earth turbidity standard. All subculture slants, plates, etc., were counted after 2 days incubation at 37° C. All tests were conducted at 20° C. All chlorine concentrations have been calculated on the basis of 1 cc. of 0.1 N. sodium thiosulphate solution representing 0.003546 g. of available chlorine, in order to avoid misunderstandings concerning the use of the term "active chlorine."

1. Burri Slant Method

After 200 p.p.m. solutions of the various products had been prepared and tempered to 20° C. one cc. of suspension of *Staph. aureus* was pipetted into 20 cc. of test solution. This amount of inoculum was sufficient to give a concentration of ten million cells per cc. in the test solution. At suitable intervals ranging between ¼ and 30 minutes, a small loopful (1/3000 cc.) of seeded solution was spread over the surface of a nutrient agar slant and this subsequently incubated. Table 1 contains data from a typical run. In order that the correlation between pH and germicidal speed might be more evident, the six products have been arranged in order of increasing pH (as determined with the glass electrode some weeks after

TABLE 1.—GERMICIDAL POTENCY OF SIX CHLORAMINE-T PRODUCTS (200 P.P.M. AV. CL.) AS MEASURED BY THE BURRI SLANT METHOD. 20° C. JANUARY 19, 1934

Product	pH	Ranking by indicator test	Period of Exposure (minutes)							
			¼	½	1	2	5	10	20	30
Chloramine-T USP	7.31	1	+++	++	140	0	0	0	0	0
Sterichlor	8.61	2	+++	+++	+++	+++	++	+	7	0
XCEM	8.66	2	+++	+++	+++	+++	+++	+	2	0
Wyandotte Sterilizer	8.7	2	+++	+++	+++	+++	+++	+	6	0
Klenocide (liquid)	9.23	3	+++	+++	+++	+++	+++	+++	++	250
Klenocide (powder)	9.92	4	+++	+++	+++	+++	+++	+++	+++	++

N.B.—Density of growth is indicated by the number of plus signs, where the number of colonies was too great to count.

the germicidal tests). In the third column is also given the ranking of the products in order of increasing alkalinity as judged by the indicator test referred to in the following section.

2. Indicator Method

In the preceding paper (*10*) details were given of a simple testing method whereby a series of hypochlorites could be arranged in order of germicidal potency. This test was based upon the close correlation between potency and pH, and made use of the fact that different hypochlorite solutions to which a definite quantity of powdered phenolphthalein had been added, assumed various shades of red and magenta depending upon the pH. While the available evidence indicates that the pH plays an equally important role with the chloramine-T solutions (*2*, *13*, *18*) the above technique is not equally satisfactory, since on account of the lower range of pH of these solutions the majority remain colorless. A more satisfactory ranking may be obtained by substituting three drops of 1% alcoholic solution of the same indicator, since the color formed is quite stable and does not fade out as is the case with the hypochlorites. The results obtained with the alcoholic indicator test are included in Table 1.

3. Glass Slide Method

This method, described in detail in the previous paper (*10*), was developed in order to approximate more nearly to the actual conditions under which chlorine solutions are employed in plant practice. The test organisms are present in a film of diluted milk upon the lower half of a microscopic slide, which is gently agitated in the test solution during the period of exposure, then placed in a petri dish and nutrient agar poured to check further action of the chlorine. Since it was natural to expect that with a higher concentration of chlorine the killing time would be greatly reduced, the solutions were tested at a concentration of 2,000 p.p.m. available chlorine in order to avoid the long exposure periods employed with the Burri slant method. Results obtained with the same six chloramine-T products are presented in Table 2.

TABLE 2.—GERMICIDAL POTENCY OF SIX CHLORAMINE-T PRODUCTS (2000 P.P.M. AV. CL.) AS MEASURED BY THE GLASS SLIDE TECHNIQUE. 20° C. MARCH 20, 1934

Product	pH	Period of Exposure (minutes)								
		¼		½		1		2		5
Sterichlor	8 32	**1**		0	0	0	0	0		
XCEM	8 38	**0**		0	0	0	0	0		
Wyandotte Sterilizer	8 50	**70**		5	2	5	0	0		
Chloramine-T U.S.P.	9 18	**99**[1]	**31**[1]	189	65[1]	2[1]				
Klenocide (liquid)	9 20	+		+		+	28[1]	**1**	**1**	0
Klenocide (powder)	9 84	+		+	+	+	+	208	81	**0**

N.B.—Estimated count 35,000 on control plates. The counts in black type mark the shortest exposure period where the average value indicates 99.75% destruction.

[1] Spreaders on these plates probably resulted in unduly low counts.

Effect of Dilution Upon pH and Germicidal Potency

A comparison of the pH values at 200 p.p.m. (Table 1) and at 2,000 p.p.m. (Table 2) reveals that *with five of the products studied the pH is actually greater at 200 p.p.m.* With chloramine-T U.S.P., however, the reverse is true, the pH having declined from 9.18 at 2,000 p.p.m. to 7.33 at 200 p.p.m.[3] This extraordinary behaviour of the five commercial products upon dilution prompted more detailed studies of the influence of dilution upon pH, some results of which are presented in Figure 1. In these studies the autoclaved distilled water used in preparing all solutions was at pH 5 8. Curve A (chloramine-T U.S.P.), is similar in form to a number obtained with commercial hypochlorite solutions similarly diluted with autoclaved distilled water (pH *ca* 6.0). Curve B (XCEM) shows a continual increase in pH on dilution until the concentration of available chlorine is reduced to 25 p.p.m. following which the pH declines sharply as the degree of dilution is increased. It had been observed that this product, as well as several others furnishing similar curves, effervesced strongly upon the addition of acid, and it was suspected that sodium bicarbonate was present as a "filler." Therefore, in order to determine whether sodium bicarbonate played any part in this anomalous behaviour a solution was prepared containing one part of chloramine-T U.S.P. to four parts of sodium bicarbonate and the pH measured at various dilutions. These data are shown in curve C. Finally, the pH values for the bicarbonate itself were obtained and are shown in curve D. The close parallelism between curves B, C and D suggests that sodium bicarbonate is responsible for the peculiar increase in pH on dilution exhibited by the five commercial chloramine-T products.

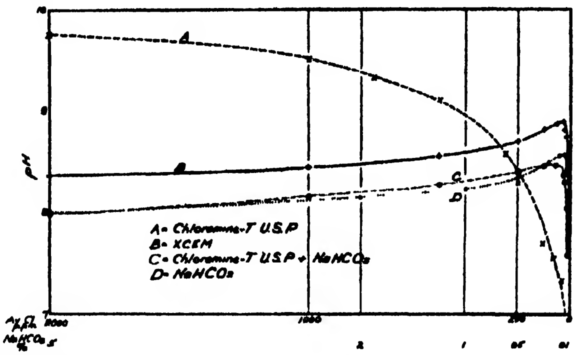

FIGURE 1. Effect of dilution upon the pH values of various solutions.

While the commercial chloramine-T products containing bicarbonate as "filler" may be expected to become steadily less effective from a germicidal standpoint on dilution within the range studied, in the case of the chloramine-T U.S.P., the totally different type of pH-concentration curve suggests that the relationship between concentration and germicidal efficiency may be more complex. Charlton (*2*), in a comprehensive study of the ability of solutions of 4000, 2000 and 1000 p.p.m. of chloramine-T to destroy spores of *Bacillus metiens* (*nov. sp.*) at 25° found that doubling the concentration resulted in a reduction of the killing time to approximately one-half. In the data presented in Tables 1 and 2 of the present paper, it will be observed that at 2000 p.p.m. the U.S.P. product is relatively

[3] It should be noted that the pH values shown in Tables 1 and 2 were obtained from solutions prepared on March 19th, the germicidal tests conducted on the 20th and the pH determination made on the 21st. Subsequent experience has shown that such solutions, especially chloramine-T U S.P., when held in stoppered volumetric flasks at room temperature, become less alkaline, which doubtless explains the lower values recorded here than will be shown further on.

less effective than three of the five commercial products, while at 200 p.p.m. it proved to be decidedly superior to all five. In the previous paper (*10*) data were presented concerning the effect of dilution upon the germicidal efficiency of an alkaline hypochlorite product (HTH–15). It was found that after declining to a certain point, germicidal activity actually increased upon further dilution. In order to determine whether the same thing might hold true for chloramine-T U.S.P., data on the germicidal efficiency of various concentrations were obtained by the Burri slant, glass slide and plate count methods, and are presented in Figure 2. For convenience in graphical presentation, the end-point has been taken as the destruction of 99.9% of the test organisms for the Burri and plate count methods, and 99.75% for the glass slide method. In the plate count method, the initial number of organisms introduced was reduced to 100,000 per cc. in order that 99 9% reduction would leave a readily countable number of colonies on the plates. In addition, one cc. of sterile N/1 solution of sodium thiosulphate was placed in each petri dish to act as a anti-chlor when the one cc. portion of seeded test solution was transferred to the petri dish at the conclusion of the exposure period.

DISCUSSION

From the data presented, it is evident that the evaluation of the germicidal potency of a series of chloramine-T products is not always a simple matter. For a given concentration of chlorine, any one of the three bacteriological testing methods employed furnishes a satisfactory indication of the relative germicidal speed, while the same holds true for the indicator method. The effect of dilution upon pH is such that the relative efficiency of the commercial products is unlikely to change within the range of concentration studied. With the chloramine-T U.S.P. however, the quite different effect of dilution upon pH results in marked fluctuations in germicidal efficiency as the available chlorine concentration is lowered. Consequently, where the latter is included in a series, its ranking relative to the commercial products will vary according to the concentration at which the tests are conducted. It is therefore necessary that all tests be carried out with solutions of the strength at which they are to be employed in practice.

No definite statement is justifiable concerning the most effective concentration of a chloramine-T product. With the five commercial products studied, it is evident that increasing the concentration within the range at which these products are generally employed results in a definite increase in germicidal potency. On the other hand, the data obtained on chloramine-T U.S.P. with three different testing methods indicate a different state of affairs. While the correspondence between the results from these three methods is by no means exact, there is nevertheless considerable agreement in the general trend of the curves. All three indicate a decline in efficiency to a point in the neighborhood of 1000 p.p.m. followed by a definite increase in efficiency to a point at approximately 200 p.p.m. Beyond this the results are less concordant, the Burri slant method showing a decline on further dilution which is less definite and pronounced for the plating method. Unfortunately, the tests with the glass slide method were not continued below 200 p.p.m.

It will also be observed that the slope of the curve for concentrations in excess of 1000 p.p.m. is definitely steeper for the Burri slant and glass slide methods than for the plating method. A likely explanation for this discrepancy lies in the fact that with the first two methods no antichlor treatment was employed, and the small amount of strong chloramine-T solution carried over in subculturing continued to act upon some of the cells after transfer to the slant or petri dish. An examination of the data obtained with the glass slide method, particularly comparing 4,000 and 2,000 p.p.m. with the lower concentrations, lends support to this hypothesis.

It should be borne in mind that the results reported in this paper deal with the effect of dilution with autoclaved distilled water, the reaction of which was in the vicinity of pH 6.0. With a more alkaline water, the effect of dilution upon the products which contain bicarbonate would presumably be much the same, while with the U.S.P. product, it would doubtless affect the steepness of the pH-concentration curve and possibly the relative germicidal potency at different concentrations.

The peculiar fluctuations in germicidal efficiency of chloramine-T U.S.P. on dilution as exhibited in Figure 2 require an explanation. In the previous paper (*10*), the variation in potency of a hypochlorite solution on dilution was noted and an explanation offered. This explanation was based upon the fact that hypochlorous acid is generally conceded to be the germicidally active constituent and that the ratio of this acid to sodium hypochlorite is a function of the pH of the solution. Calculation of the concentration of hypochlorous acid present at various concentrations of total available chlorine between 25 and 1 p.p.m. afforded data supporting the above explanation. The question naturally arises as to whether a similar hypothesis would serve to explain the anomalous behaviour of chloramine-T U.S.P. In the first place it seems possible that traces of hypochlorous acid may be formed in chloramine-T solution. Charlton (*2*) states, "Whether chloramine-T exerts a germicidal action by means of HOCl or in some other way, cannot be definitely stated." Süpfle (*19*) quotes Hailer (*6*) to the effect that chloramine-T in aqueous solution forms sodium hypochlorite and p-toluenesulphonamide. This appears to be not unreasonable since chloramine-T is prepared by dissolving p-toluenesulphonamide in sodium hypochlorite (*4*) and we may therefore expect hypochlorous acid to be formed from the chloramine-T, although doubtless in very much smaller amounts than in a hypochlorite solution of equivalent chlorine strength and pH.

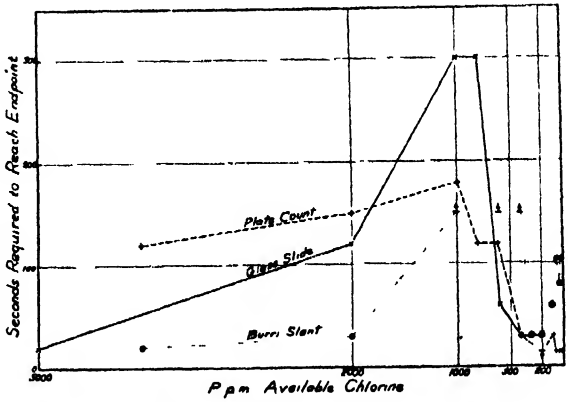

FIGURE 2. Effect of dilution upon germicidal efficiency of chloramine—T U.S.P., as judged by three different testing methods.

In order to measure the quantity of hypochlorite present in water containing various chlorine and chlorine-ammonia compounds, Holwerda (*7*) employed the methyl orange titration method developed by Massink (*14*). This suggested the possibility of employing this reaction to discover whether or not hypochlorite is present in a chloramine-T solution. This test is apparently intended for the estimation of very small quantities of hypochlorite, for with a 20 p.p.m. solution of chloramine-T no definite end-point could be obtained. However, tests on 1 p.p.m. solution were more satisfactory, 0.4 cc. of methyl orange solution being required per 100 cc. as compared with 1.89 cc. per 100 cc. of a 1 p.p.m. hypochlorite solution of low alkalinity (HTH). If this reaction is specific for chlorine in the form of hypochlorite, as Besemann claims (*1*), then the above results indicate that hypochlorous acid is present to some slight extent in a dilute solution of chloramine-T.

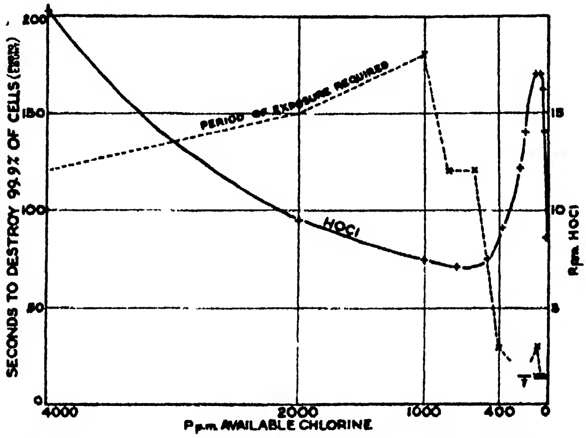

FIGURE 3. pH and assumed HOCl concentration of solutions of chloramine—T U.S.P., containing varying amounts of available chlorine.

Charlton (*2*) as a result of his investigations concluded that "in the absence of added organic matter it requires about 100 times as much available chlorine in the form of Chloramine-T as in the form of hypochlorite to destroy vegetative cells." If therefore we assume that the germicidal activity of a chloramine-T solution is dependent upon the amount of hypochlorous acid present, and that the latter is present in 1/100 of the concentration that would be expected in a hypochlorite solution of equivalent chlorine strength and pH, we may calculate by means of the Henderson-Hasselbalch equation, pH = pKa + log salt/acid, the assumed concentration of hypochlorous acid for various concentrations of chloramine-T. This has been done and the results are plotted in Figure 3 together with the pH-concentration curve. In order to facilitate comparison between germicidal efficiency and hypochlorous acid concentration the curve for the assumed concentration of hypochlorous acid has been similarly plotted along with the end-point data obtained with the plate count method (Figure 4). It will be observed that a substantial agreement exists between the assumed concentration of hypochlorous acid as calculated and the germicidal potency, indicating that the tentative explanation offered above may be fairly close to the truth.

It should be pointed out that the assumed concentrations of hypochlorous acid as calculated above are very much higher than those calculated for sodium hypochlorite solutions in the previous paper. For the latter, the values were 0.013 for 25 p.p.m., 0.014 for 10 p.p.m. and 0.03 for 2 p.p.m. available chlorine. The latter concentration of sodium hypo-

chlorite was approximately equal in effectiveness to 400 p.p.m. of chloramine-T U.S.P. solution, for which the calculated concentration of hypochlorous acid, based upon Charlton's estimate is 9 p.p.m. It appears therefore that if hypochlorous acid is actually present, the actual concentration in a given content of available chlorine would be much less than 1/100 of that existing in a sodium hypochlorite solution of equivalent pH and available chlorine concentration.

With regard to the effect of dilution upon the pH values of chloramine-T products containing bicarbonate (Figure 1), such an unexpected finding as an increase in alkalinity on dilution of a slightly alkaline product with distilled water of pH *ca* 6.0 suggested that this effect might be peculiar to the use of the glass electrode. However, similar curves have been obtained with sodium bicarbonate solutions tested out colorimetrically with thymol blue and phenol red, and electrometrically with the quinhydrone electrode. Furthermore, solutions prepared from different lots of sodium bicarbonate (Merck's and Baker's) and distilled water from different laboratories have all shown the same tendency to increase in pH on dilution, and a similar effect was observed with potassium bicarbonate, indicating that the explanation must be sought elsewhere.

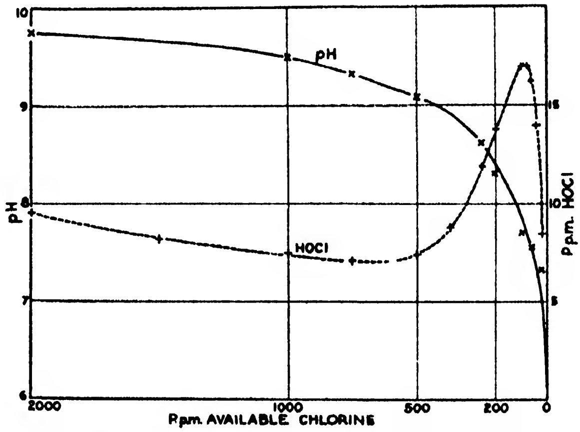

FIGURE 4. Relation between assumed concentration of HOCl and germicidal speed of solutions of chloramine-T U.S.P. containing varying amounts of available chlorine.

It is of interest to record here that Lepper and Martin (*12*) in studying the discrepancy between colorimetric and electrometric (hydrogen electrode) determinations of the pH of blood serum, present data concerning the pH of solutions of 0 02 M sodium bicarbonate containing decreasing amounts of sodium chloride. As the concentration of sodium decreases, the pH increases, although the concentration of bicarbonate is uniform throughout. No data are recorded concerning bicarbonate solutions in the absence of sodium chloride. These workers believed this anomalous behaviour to be due to the concentration of sodium ion and its influence on dissociation in accordance with the mass law. Cullen (*3*), in studying the pH of blood plasma, noted that serum showed a continuous increase in alkalinity when diluted with 0.9% sodium chloride solution up to a dilution of fifteen to twenty-fold, and further stated, "The use of salt solution instead of water as a plasma diluent is necessary because the curve is . . . . steeper with water than with saline solution . . . ." Cullen made no attempt to explain this peculiar effect of dilution, nor will any be made here, such investigations being beyond the scope of the present studies. The effect is of interest primarily because of the fact that

commercial chloramine-T products containing bicarbonate, unlike the U.S.P. product, become steadily less effective on dilution over the range studied.

SUMMARY

Three bacteriological methods and one chemical (colorimetric) method have proven useful in evaluating the relative germicidal efficiency of chloramine-T products in the absence of large amounts of organic matter.

The effect of dilution on the pH of the commercial products studied was most unexpected, the solutions becoming *more alkaline* on dilution with distilled water of slightly acid reaction. Since sodium bicarbonate, known to be present as a filler in commercial products, behaves similarly, this anomalous increase in alkalinity on dilution may be attributed to the presence of bicarbonate. Within the range of 2,000 to 25 p.p.m. available chlorine, these products may be expected to decline in germicidal activity on dilution.

Solutions of chloramine-T U.S.P. on the other hand decrease in alkalinity on dilution, furnishing a pH-concentration curve similar to that for a hypochlorite solution. The germicidal potency, however, does not decline uniformly on dilution; below 1,000 p.p.m. the activity increases to a point around 200 p.p.m., falling off again beyond this. On the assumption that chloramine-T yields a trace of hypochlorous acid in solution the assumed concentrations have been calculated from pH data and are found to be in substantial agreement with the fluctuating germicidal potency.

Acknowledgments

The writer wishes to express his thanks to Dr. A. G. Lochhead, Dominion Agricultural Bacteriologist, for advice upon certain phases of the work, and to Messrs. A. H. Jones, B.S.A., and G. B. Landerkin, B.S.A., for assistance in connection with the germicidal testing.

LITERATURE CITED

1. Besemann, Dr. Chem. Zeit, *52* : 826. 1929.
2. Charlton, D. B. Doctorate thesis, Iowa State College. 1933.
3. Cullen, G. E. J. Biol. Chem. *52* : 501-515. 1922.
4. Dakin, H. D., Cohen, J. B. and Kenyon, J. Brit. Med. J. 1 : 160-162. 1916.
5. Devereux, E. D. and Mallmann, W. L. J. Dairy Sci., *17* : 351-360. 1934.
6. Hailer, E. Centr. f. Bakt. 1 Abt. 89, 2*-15*, 1922, 1 Abt. etc.
7. Holwerda, K. Mededeel. Dienst. Volksgezondheit Nederland-Indië, *17* : 251-297. 1928.
8. ———— Mededeel. Dienst. Volksgezondheit Nederland-Indië, *19* : 326-385. 1930.
9. Johns, C. K. Sci. Agr. *10* : 553-563. 1930.
10. ———— Sci. Agr. *14* : 585-607. 1934.
11. Koser, A. Centr. f. Bakt. 1 Abt. *99* : 164-171. 1926.
12. Lepper, E. H. and Martin, C. J. Biochem. J. *20* : 45-58. 1926.
13. Loveless, W. G. Vermont Agr. Exp. Sta. Bul. 369. 1934.
14. Massink, A. Chem. Weekblad, *23* : 329-34. 1926.
15. Myers, R. P. Proc. Intern. Assoc. Milk Dealers, Lab. Sect. *23* : 75-85. 1930.

16. Myers, R. P. and Johnson, A. H. Proc. Intern. Assoc. Milk Dealers, Lab. Sect. *25* : 21-55. 1932.

17. Prucha, M. J. 16th Ann. Rept. Intern. Assoc. Dairy and Milk Inspectors, 319-328, 1927.

18. ———— 22nd Ann. Rept. Intern. Assoc. Dairy and Milk Inspectors, 70-80. 1933.

19. Süpfle, K. Arch. f. Hygiene, *97* : 176-182. 1926.

20. Tilley, F. W. J. Agr. Res. *20* : 85-110. 1920.

Résumé

L'évaluation de la puissance germicide des composés de chlore. II. Produits de chloramine-T. C. K. Johns, ferme expérimentale centrale, Ottawa, Ont.

Trois moyens bactériologiques et un moyen chimique (colorimétrique) se sont montrés utiles pour évaluer la capacité germicide relative des produits de chloramine-T (ou Tochlorine) en l'absence de grandes quantités de matières organiques. L'effet de la dilution sur le pH des produits commerciaux à l'étude a été des plus inattendus. Les solutions devenaient *plus alcalines* lorsqu'elles étaient diluées avec de l'eau distillée ayant une réaction légèrement acide. Comme le bicarbonate de soude que l'on sait être présent comme substance de remplissage dans les produits commerciaux se comporte de la même façon, cette augmentation anormale de l'alcalinité par dilution peut être attribuée à la présence du bicarbonate. On peut s'attendre à voir la faculté germicide de ces produits diminuer après dilution dans la proportion de 2,000 à 25 p.p.m. de chlore utile. Par contre, l'alcalinité des solutions de chloramine-T U.S.P., diminue après dilution, fournissant une courbe de concentration du pH semblable à celle d'une solution d'hypochlorite. Cependant la puissance germicide ne diminue pas uniformément après dilution; au-dessous de 1,000 p.p.m. l'activité augmente jusqu'à un point touchant 200 p.p.m. et diminue à nouveau lorsque ce point est dépassé. Se basant sur la supposition que la tochlorine (Chloramine-T) rend une trace d'acide hypochloreux en solution, l'auteur a calculé les concentrations supposées d'après les données du pH et a trouvé qu'elles sont conformes à la puissance germicide fluctuante.

STUDIES ON THE CONTROL OF ROOT ROT DISEASES OF CEREALS CAUSED BY *FUSARIUM CULMORUM* (W. G. SM.) SACC. AND *HELMINTHOSPORIUM SATIVUM* P., K., AND B.

I. FIELD METHODS WITH ROOT ROT DISEASES.[1]

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INTRODUCTION

Root rot diseases of cereals caused by species of *Helminthosporium* and *Fusarium* are wide-spread and destructive in the three prairie provinces of Canada. In certain localities they are a limiting factor in the production of cereals *(4)*. The production of resistant varieties of cereals by breeding offers the most promising method of controlling these diseases. Other control measures aim at the destruction of the fungi on the seed and in the soil.

To differentiate between varieties of cereals for resistance and susceptibility to root rots, and to determine the effectiveness of various seed and soil treatments for the control of these diseases, it is necessary to produce artificially annual attacks of epidemic severity. In the field it is difficult to do this. The problem involves not only the development of practical and efficient devices to induce disease attacks, but the development of reliable methods of recording and analyzing root rot experimental data. This paper presents the results of three years' experiments designed to give effective and practical field methods of insuring positive attacks with the common cereal root-rotting fungi *Fusarium culmorum* (W. G. Sm.) Sacc. and *Helminthosporium sativum* P., K., and B.

It may be mentioned in passing that species of *Fusarium* and *Helminthosporium* occur together in the soil and are frequently isolated from the same diseased portion of the underground plant parts. Consequently, in this paper, the term "root rot" is used to designate a diseased condition of the base and roots of the plant. The term thus includes the various manifestations—seedling blight, foot-rot or crown-rot, and root-rot—caused by attacks of *F. culmorum* and *H. sativum.*

The general problem of root rot diseases of small grains has received considerable attention in many countries. Bolley *(1)*, Cordley *(3)*, Stevens *(18)*, Henry *(9)*, McKinney *(12)*, Christensen *(2)*, Simmonds *(16)*, Greaney and Bailey *(8)*, and others, have shown the great economic importance of these diseases in Canada and the United States. The literature on the subject has been thoroughly reviewed by these workers.

EXPERIMENTAL METHODS

The land on which the field experiments were conducted each year consisted of well-tilled, summerfallowed clay soil at Winnipeg, Manitoba.

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It had been cropped in a uniform manner the previous year, and cultural conditions during each growing season were uniform throughout.

Plan of Experiments.—Five different methods of introducing F. *culmorum* and *H. sativum* into the soil were tested in 1931 and 1932 on three varieties of wheat, one of oats, and one of barley. The Latin Square arrangement of blocks was used for the varieties, and eleven plots, representing five treatments with each organism and an untreated check, were randomized within each block. Each plot consisted of two rod-rows, one in which the seeds were spaced in the row, 100 seeds per row, and the other in which a weighed amount of seed, according to the variety, was sown by hand and distributed evenly along the row. The former row was used for estimating the amount of disease in each plot, while the latter furnished the yield data. The rows were planted one foot apart, and the complete experiment consisted of 175 plots.

A second experiment was made in 1932 in which five different methods of artificially inducing root rot attacks were tested with each of the fungi, *H. sativum* and *F. culmorum*, on Marquis wheat. A Randomized Block arrangement of plots was used, incorporating each treatment with each organism in each block. There were six blocks in this experiment.

Two distinct experiments were made in 1933, one with the fungus *F. culmorum* and another with *H. sativum*. In each experiment eight different methods of introducing the fungus into the soil were studied. The Randomized Block plan of plot experiment was employed, and the blocks were adequately replicated. Marquis wheat was used in both experiments.

Varieties and Organisms.—Marquis, Mindum and Marquillo wheat, Banner oats, and Canadian Thorpe barley were the varieties used in 1931 and 1932. The seed was obtained from pure line material and selected for uniformity in size and plumpness, but it was not surface-sterilized. In 1933, Marquis only was used. In that year the seed, in order to insure a positive attack with root-rotting fungi, was injured slightly by scarifying with sand-paper.

The strain of *Fusarium* used in the field experiments was isolated originally in 1930 from a rotted crown of Marquis wheat, and was identified by Dr. W. L. Gordon, Dominion Rust Research Laboratory, Winnipeg, as *Fusarium culmorum* (W. G. Sm.) Sacc. The strain of *Helminthosporium sativum P.*, K., and B. used was obtained in 1930 from diseased roots of barley. Repeated greenhouse tests demonstrated that both fungi were highly pathogenic on wheat, barley and rye. The strain of *F. culmorum* studied was distinctly pathogenic on oats.

Methods of Infesting Soil.—Two principal methods were used to introduce *H. sativum* and *F. culmorum* into the soil. The first method consisted of applying a solid medium, overgrown with the fungus to be tested, to the soil at seed level. Adding spores of the fungus to the seed before it was sown constituted the second method.

As Sallans *(14)* has pointed out, oat-hull mash provides an excellent medium for the development of *H. sativum.* Simmonds *(16)* found finely-ground oat hulls to be an excellent medium on which to grow *F. culmorum.* For the purpose of the present studies the fungi were grown on sterilized oat-hull mash in one-half gallon jars. This medium, when

completely overgrown with mycelium bearing numerous spores of the fungus (oat-hull inoculum), was applied in various amounts to the soil. Another type of solid medium used for introducing root-rotting fungi into field soil consisted of one part oat-hull inoculum to nine parts of autoclaved soil, by volume. This mixture (soil inoculum) was incubated for two weeks and then applied at the rate of 600 cc. per rod row. The solid media were applied at seeding time and distributed uniformly at seed level in each row.

The method of applying spore suspensions to seed has been used with considerable success by Stakman *(17)*, McKinney *(11)*, and Sallans *(14)*, to introduce *H. sativum* into the soil. Simmonds *(16)*, in some greenhouse tests, produced foot-rot and seedling blight of oats by drying spore suspensions of *F. culmorum* on the seed. Wherever this method was used in the present field studies the seed was inoculated with a heavy suspension of conidia of the fungus, dried rapidly, and sown a few hours later.

The solid-medium and spore-suspension methods of introducing pathogenic fungi into the soil have been tested singly, and in various combinations.

Recording Disease Infection and Yield Data.—Fifteen days after planting, germination counts were taken on the spaced-seed row of each plot in the experiment. The plots were under observation continuously and the development of the disease was observed on the plants in the control plots. Approximately ten days before harvest, when the crop was still green, the plants in the spaced-row of each plot were lifted, counted, and examined individually, and the severity of infection on the basal parts recorded. A modification of the method described by McKinney *(11)* was used in recording the extent of disease. Each plant was given a numerical rating based on the degree of infection, and the final disease rating for the plants grown in a given plot was computed from the sum of all the numerical ratings. The numerical ratings used in this study are described in Table 1.

TABLE 1.—NUMERICAL CLASSES USED IN RATING HEALTHY AND DISEASED CEREAL PLANTS GROWN IN FIELD SOIL INFESTED WITH ROOT-ROTTING FUNGI

Class	Extent of disease on underground parts	Numerical rating
1	No infection	0
2	Small lesions on sheaths, coleoptile or roots	1
3	Distinct lesions on underground parts; with severe rotting of coleoptile	2
4	Numerous large lesions on roots and basal parts of plant	3
5	Plant stunted, with complete rotting of coleoptile and sheaths. Roots badly rotted; and culms dead	4
6	Dead plant. Plant fails to emerge, or is killed before maturity	5

$$\text{Disease Rating} = \frac{\text{Sum of numerical ratings} \times 100}{\text{Total number of seeds planted} \times 5}$$

The result is then a comparative infection rating for each treatment. The results from all plants grown in a given experiment were compared on a basis of factors derived according to the above method for each treatment.

In determining the disease rating it was assumed that all seeds planted in the spaced-row of each plot were capable of germination. Repeated germination tests indicated that from 96 to 100% of the seed used was viable. It is important to point out, however, that, in field tests with root rot diseases of cereals, it is often difficult to determine whether non-emergence is due to parasitic attack or to poor germination of the seed. Furthermore, it is impossible to prevent contamination from common soil-inhabiting organisms.

The yield data of each treatment were secured by harvesting and threshing separately the second rod row of each plot.

According to the methods described above, two complete sets of data (disease rating and yield) were obtained for a given treatment in each experiment. To obtain information as to the significance of the differences observed between different methods of introducing pathogenic fungi into the soil, the experimental data were treated by the "Analysis of Variance" method and Z test (Fisher *(6)*). The method of analyzing the data cannot be described here in detail, and reference should be made to Fisher *(6)*, Fisher and Wishart *(5)*, and Goulden *(7)*.

ANALYSIS OF DATA

Relation Between Root Rot Disease Rating and Yield

Accurate measurement of the intensity of the diseases caused by root-rotting fungi on cereals is essential in studying these diseases. Without measurement it is impossible to decide if the amount of disease on treated plots is greater or less than on untreated ones, or to estimate accurately the degree of susceptibility and resistance, or to estimate the economic importance of root rot diseases. As cereal crops are grown for the amount of grain produced, it is essential that any measurement of root rot disease intensity should bear relation to the yield of grain.

In experimental plot work detailed measurements are possible, the chief deterrent from making them being the time and labour involved. The requirement is a simple and reliable method that can be standardized for measuring the amount of disease in different experiments and in different years. The method adopted in the present experiments is described above. Since the classification involved requires personal judgment it is most essential that one observer make all the measurements on any given experiment. If two or more observers have to make measurements they must work by some simple numerical scale and frequently check their observations.

The importance of accurate measurement in dealing with the root rot problem cannot be over-emphasized. The obtaining of such data requires a very careful arrangement of experimental plots with considerable replication, in other words, the employment of modern methods of field experimentation. Owing to the complexity of the root rot problem and the nature of the difficulties involved, the degree of replication and the size and number of samples to be taken, if statistically significant results are to be obtained, are much larger than have usually been taken in the past.

In the final analysis of the results of each experiment, in order to discover whether or not the disease rating constituted a reliable method of recording the amount of injury caused by *H. sativum* and *F. culmorum* on wheat, disease ratings and the yields of individual plots were correlated. The significance of the correlation coefficients so obtained was determined according to the method described by Fisher *(6)*. Correlation coefficients for disease rating and yield in these experiments, and the computed values of *t*, are given in Table 2.

TABLE 2.—CORRELATION COEFFICIENTS FOR ROOT ROT DISEASE RATING IN RELATION TO THE YIELD OF WHEAT. RESULTS OF FIELD EXPERIMENTS WITH MARQUIS AND MINDUM WHEAT

Year	Variety	Organisms	Correlation coefficient	t*
1931	Marquis	*H. sativum* and *F. culmorum*	−0 32	2 48
	Mindum	*H. sativum* and *F. culmorum*	−0 52	4 47
1932	Marquis I	*H. sativum* and *F. culmorum*	−0 39	3 05
	Mindum	*H. sativum* and *F. culmorum*	−0 63	5.93
	Marquis II	*H. sativum* and *F. culmorum*	−0 69	6 22
1933	Marquis	*H. sativum*	−0.62	6.05
	Marquis	*F. culmorum*	−0 80	10 34

*5% point = 2·04 1% point = 2·75

The significant negative correlations given in Table 2 indicate that increases in the amount of root rot, as expressed by the disease rating, result in decreases in yield. In all experiments the correlations were highly significant. The results of the analysis establish the fact that the disease rating is closely related to the yield, and hence constitutes an accurate measurement of the amount of root rot caused by *H. sativum* and *F. culmorum* on wheat under field conditions.

As no marked seasonal differences occurred at Winnipeg during the growing periods of 1931, 1932 and 1933, it may be assumed that the positive attacks of root rot obtained in 1933 were brought about by improvements in field technique. Undoubtedly the high degree of association between disease rating and yield (−0.80) obtained in that year, in plots infested with *F. culmorum*, was due, in part at least, to the employment of scarified seed. Machacek and Greaney *(13)* have demonstrated that the use of mechanically injured seed promotes the development of root rot caused by *F. culmorum* on cereals, thereby retarding the growth of the plants and decreasing yield.

The results of the analysis in Table 2 show that root rot diseases caused by *H. sativum* and *F. culmorum* have a marked detrimental effect on the yield of wheat.

Results with *Helminthosporium Sativum*

Examination of the results of experiments with *H. sativum* (Table 4) indicated strongly that a real effect due to different methods of infesting soil was being studied. In order to verify the results, a thorough examination of the data was essential. Fisher's analysis of variance method has

been utilized for this purpose. This method for the analysis of Randomized Block experiments permits an evaluation of the significance of the experiment as a whole, as well as of the individual treatments. Table 3 gives the analysis of variance of a modified Randomized Block experiment with *H. sativum*, and illustrates the method of analysis utilized in all field experiments reported in this paper.

TABLE 3.—COMPLETE ANALYSIS OF VARIANCE FOR DISEASE RATING AND YIELD OF THE 1933 *Helminthosporium* EXPERIMENT

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5 per cent point
Disease Rating					
Units	2	61.67	30 83		
Rows	3	118 38	39 46		
Columns	3	88 87	29 62		
Treatments	9	1,585 62	176 18	1 1430	0.3726
Error	42	752 52	17 91		
Total	59	2,607.06			
Yield					
Units	2	304 43	152 21		
Rows	3	37 60	12 53		
Columns	3	10 60	3 53		
Treatments	9	314 60	34 95	1 0876	0 3726
Error	42	166 92	3 97		
Total	59	834 15			

If no treatment differences existed the variances estimated from treatments (Table 3) would be expected to differ from the error variances only by an amount which might be obtained by chance. In this experiment the variances due to treatments are much greater than the variances due to error. The significance of the results, however, is assessed by the "Z" test, in which the variances due to any known cause is compared with the variance due to error. The 5% probability value, which is the value which Z must attain to assure a probability of 20 to 1 against the result obtained being merely due to chance, was used in these studies. The values of Z for soil treatments are given in Table 3.

The statistical analysis clearly establishes the significance of soil treatment differences and a more detailed examination of the results can be made. The standard errors of the experiment were calculated directly from the variance tables, and the standard errors of the means of treatments are given in Table 4.

In the present studies it is considered that, to be significant, a minimum difference between any two treatments should be three times the standard error. For an easy inspection of the results and their significance, all significant values in Tables 4 and 5 are given in heavy type.

TABLE 4.—RELATIVE EFFECT OF DIFFERENT METHODS OF INFESTING FIELD PLOTS WITH THE FUNGUS *Helminthosporium sativum* ON THE AMOUNT OF ROOT ROT INFECTION, AND ON THE CONSEQUENT YIELD OF CEREAL VARIETIES IN 1931, 1932 AND 1933, AT WINNIPEG, MAN.

Disease Rating

Year	Kind and amount of inoculum per rod row										
	Oat-hull (grms.)				Soil 600 cc.	Seed (spore susp.)	Seed (s.s) plus soil (600 cc.)	Seed (s s.) plus oat-hull (120 grms.)	Seed (s s.) plus soil, plus oat-hull	Control	Standard error of means of treatments
	40	80	120	160							
1931	60 8	**62 8**	**62 8**	**66 2**	59 0					59.0	1 10*
1932 I		60 9	59 0	59 5	59 9	**62 2**				57.8	1.31
1932 II			66 0		68 0	64.2	68 0	**76 5**		68.0	2 40
1933	**72 0**	**72 7**	**79 3**		66 5	**76 4**	**73 3**	**82.4**	77.8	66.2	1.73
	Yield (Bushels per acre)										
1931	34 2	34 5	32 7	32 9	35 5					36 0	
1932 I		43 1	41 8	37 6	43 9	40 4				42 7	1 97
1932 II			14 2		13 8	17 6	17 4	16 5		16 7	2 29
1933	21 8	**20 0**	**20 1**		24 1	**19 0**	**20 0**	**16 4**	**18 0**	22 8	0.81

*To be significant the differences between means of treatments must exceed $2\sqrt{2} \times 1\ 10 = 2\ 96$. Significant values between soil treatments and controls are given in bold type.

To economize space the results of the three years' experiments with *H. sativum* are summarized in Table 4. From this table it will be observed that although significant differences in disease rating occur, thus indicating the effectiveness of individual methods of introducing the fungus into the soil, these are not always accompanied by significant yield differences. For the purpose of the present study the presence of statistically significant values for disease rating is only of relative value. It is considered that significant yield differences are essential in order to determine the effectiveness of any artificial method of inducing heavy root rot infection on cereals in the field.

From the data in Table 4 it will be observed that applications of oat-hull inoculum, or soil inoculum, to field soil at seed level, failed to increase the amount of root rot on cereals. In 1933 the highest degree of infection was obtained by using inoculated seed and applying oat-hull inoculum. The employment of these methods resulted in a statistically significant reduction in yield. The seed spore-suspension method gave satisfactory results in 1933, but it was not so effective in 1931 and 1932.

Sallans *(14)*, in 1930, obtained heavy field infections by inoculating wheat seed with a spore-suspension of *H. sativum*. He reported that the severity of infection was influenced by incubating the treated seed for from 18 to 27 hours at 24°C. It is possible, therefore, that a higher degree of infection with *H. sativum* than was obtained in the field experiments here reported may be achieved by standardizing the method of seed inoculation. Further studies are required to determine an effective and practical method of infesting plots of wheat and barley with *H. sativum*.

Results with *Fusarium Culmorum*

The results of three years of field experiments designed to given an effective and practical method of inducing positive attacks of root rot caused by *F. culmorum* on cereals, are presented in Table 5.

TABLE 5.—RELATIVE EFFECT OF DIFFERENT METHODS OF INFESTING FIELD PLOTS WITH THE FUNGUS *Fusarium culmorum* ON THE AMOUNT OF ROOT ROT INFECTION, AND ON THE CONSEQUENT YIELD OF CEREAL VARIETIES IN 1931, 1932 AND 1933, AT WINNIPEG, MAN.

Disease Rating*

Year	Kind and amount of inoculum per rod row										
	Oat-hull (grms.)				Soil 600 cc.	Seed (spore susp.)	Seed (s.s.) plus soil (600 cc.)	Seed (s.s.) plus oat-hull (120 grms.)	Seed (s.s.) plus soil, plus oat-hull	Control	Standard error of means of treatments
	40	80	120	160							
1931	62.1	**65.2**	**65.6**	**67.6**	**68.9**					59.6	1.10
1932 I		**63.6**	**63.2**	**66.4**	**65.5**	**80.1**				57.8	1.31
1932 II			68.0		**70.0**	**83.2**	**87.5**	**87.2**		62.2	2.40
1933	68.2	**74.4**	**76.1**		**83.8**	**97.3**	**96.4**	**96.8**	**97.4**	63.1	2.04

Yield (Bushels per acre)*

Year	40	80	120	160	Soil 600 cc.	Seed (spore susp.)	Seed (s.s.) plus soil (600 cc.)	Seed (s.s.) plus oat-hull (120 grms.)	Seed (s.s.) plus soil, plus oat-hull	Control	Standard error of means of treatments
1931	33.1	34.2	34.2	32.8	29.6					36.0	
1932 I		39.3	38.1	37.1	44.8	**29.1**				42.7	1.97
1932 II			11.9		16.3	**8.8**	**4.9**	**7.6**		16.7	2.29
1933	18.9	18.5	19.4		**16.6**	**6.3**	**6.6**	**6.2**	7.2	21.8	1.38

*Statistically significant values between soil treatments and controls are given in bold type.

From these data it is evident that although some of the oat-hull inoculum treatments were effective in that their application resulted in a higher degree of root rot infection, none of them gave significant responses in yield. When used alone soil inoculum (one part oat-hull inoculum to nine parts soil), applied at the rate of 600 cc. per rod row, gave very satisfactory results in 1933, but this treatment did not reduce yield in other years.

The most effective method employed to induce *Fusarium* root rot attacks in the field was the application of spores of the fungus to the seed before sowing. The employment of this method increased the amount of root rot, and, in 1932 and 1933, resulted in decreased yields. In these years a combination of two methods, namely, dipping the seed in a suspension of conidia before sowing and applying soil inoculum at the rate of 600 cc. per rod row, markedly increased the amount of root rot and decreased yield. In general, however, the effect on the amount of root rot infection and on the yield, of employing a combination of two or three methods to introduce *F. culmorum* into the soil, was not more marked than when the spore-suspension method alone was used.

From Table 5 it is apparent that the spore-suspension method is a very effective means of inducing positive attacks of root rot caused by *F. culmorum*. Moreover, it constitutes a practical method of artificially creating a destructive attack of this disease on cereals. A vigourously

sporulating strain of *F. culmorum* gave positive infection results in these experiments, but whether or not similar results could be obtained on cereal plants with other parasitic species of *Fusarium* is a problem requiring further investigation.

The practical possibilities of the seed spore-suspension method of producing artificial epidemics of root rot on wheat with the fungus *F. culmorum* was demonstrated in 1933. In that year a field experiment was made to compare the effectiveness of four fungicidal seed treatments for the control of root rot of wheat. This experiment was designed also to determine the effect on root rot development of two different methods of introducing the fungus into the soil.

A modified Randonized Block arrangement of plots was used, incorporating four seed treatments and three soil treatments. Seed and soil treatments were properly randomized in each block, and the complete experiment consisted of six blocks containing 72 plots. Each plot was composed of two rod rows, one in which the seed was spaced, 100 seeds per row, and the other containing 18 gms. of Mindum seed sown by hand and distributed uniformly along the row. The former row furnished the disease-rating and the latter the yield data.

One series of plots in this experiment was planted with Mindum wheat which had been previously inoculated with spores of *F. culmorum*. In another series inoculated seed was planted in soil to which 600 cc. of soil inoculum, prepared as described previously, was applied at seed level in each rod row. A third series of plots was not infested by artificial methods and served as the control. The results of the analysis of variance for disease rating and yield of this experiment are given in Table 6.

TABLE 6.—COMPLETE ANALYSIS OF VARIANCE FOR DISEASE RATING AND YIELD OF AN EXPERIMENT TO DETERMINE THE EFFECT OF SEED TREATMENTS AND SOIL TREATMENTS ON THE DEVELOPMENT OF ROOT ROT CAUSED BY *Fusarium culmorum*

Disease Rating

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5 per cent point
Controlled error	8	1,512 81	189 10		
Seed treatments	3	422 26	140 75	0 6536	0·5117
Soil treatments	2	3,774 06	1,887 03	1.9516	0 5777
Seed treatments v. soil treatments	6	1,420 20	236 70		
Error	52	2,026 07	38 96		
Total	71	9,155 40			

Yield

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5 per cent point
Controlled error	8	3,232 29	404 04		
Seed treatments	3	52 60	17 53		
Soil treatments	2	422 39	211 19	1 1116	0.5777
Seed treatments v. soil treatments	6	413 36	68 90		
Error	52	1,189 07	22.86		
Total	71	5,309 71			

The results of the statistical analysis of the data establish that, although there is a significant value for disease rating between the various fungicidal seed treatments tested, the results for yield are not significant, and hence the experiment may be assumed to be unimportant in so far as determining the efficiency of seed treatments for the control of *Fusarium* root rot of wheat. On the other hand, the results of the analysis of soil treatments in Table 6 show that the differences, both in disease rating and yield, due to methods of introducing *F. culmorum* into the soil, are significant. Statistically, therefore, the effectiveness of the soil treatments is established with a very high degree of probability, and thus the experiment confirms the finding of the Methods experiments previously detailed. Table 7 summarizes the complete results of the experiment.

TABLE 7.—RELATIVE EFFECT ON THE AMOUNT OF DISEASE AND ON THE YIELD OF MINDUM WHEAT OF DIFFERENT METHODS OF INSURING POSITIVE ATTACKS OF ROOT/ROT OF WHEAT CAUSED BY *Fusarium culmorum*

Disease Rating

Method of introducing *F. culmorum* into the soil	Seed Treatments				Mean*	Standard error of means of soil treatments
	Ceresan	DuBay	Copper carbon-ate	Control		
Seed inoculation plus soil inoculum	70 9	68 8	74 5	75 2	72 3	
Seed inoculation	65 8	64 3	71 0	76 3	69 3	0.90
Control	59 2	65 4	58 9	57 6	60 3	
			Yield (Bushels per acre)			
Seed inoculation plus soil inoculum	15 6	17 5	14 7	14 8	15 6	
Seed inoculation	19 2	18 6	18 6	14 8	17 8	0 69
Control	20.8	15 9	21 5	21 5	19 9	

*To be significant the differences between means of soil treatments must exceed $2\sqrt{2} \times$ Standard error.

Examination of Table 7 shows that the amount of root rot was markedly increased in 1933 by applying inoculum of *F. culmorum* to the seed and soil. Seed inoculation was effective when used separately, and with soil inoculum. The mean yield difference observed between plots which were planted with inoculated seed and the controls just reached significance, while the employment of both seed inoculation and soil inoculum methods to introduce *F. culmorum* into the soil resulted in a mean difference in yield between plots so treated and the controls which was statistically significant.

DISCUSSION

Henry *(9)*, and Sanford and Broadfoot *(15)* have demonstrated that the natural microflora of soil has a marked inhibitive effect on the development of cereal root-rotting fungi. Their results seem to offer a partial explanation of the frequent failures to obtain successful root infections on cereal plants where inoculum of *Helminthosporium sativum* and *Fusarium culmorum* has been applied to the soil. It would seem that, owing to the

marked influence of the natural soil flora on plant pathogens, soil, infested naturally with *H. sativum* and *F. culmorum*, would be most suitable for field experiments. Inasmuch as it is difficult to secure naturally-infested fields for experimental purposes, it is necessary to develop an effective and practical field technique for inducing positive attacks with *H. sativum* and *F. culmorum*.

Experiments here reported were made with ordinary field soil. Consequently, due to the natural fungous flora, a considerable amount of infection occurred on the roots and basal parts of cereal plants even when inoculum of a parasitic fungus had not been applied to the seed or to the soil. Tables 4 and 5 show that the degree of infection on the underground parts of plants grown in ordinary field soil (controls) was relatively severe in 1931, 1932 and 1933. These results emphasize the importance of planning root rot field experiments so that differences in disease infection and yield arising from various seed and soil treatments can be properly evaluated.

To provide a fair test of the relative effectiveness of several competing treatments for controlling soil-inhabiting fungi, such as the root rot pathogens, field plots sould be so arranged that the heterogeneity of the soil as well as differences between the treatments themselves can be accurately determined. The Randomized Block plan of plot arrangement, as used in these studies, makes a very desirable arrangement for root rot experiments. This method permits an adequate evaluation of heterogeneity arising from sources other than the treatments themselves. Furthermore, the application of statistical methods to the interpretation of field experiments is essential in order to obtain a more accurate appreciation of the experimental errors involved, and of the significance attached to any result.

The field methods described in this paper should lead to practical applications of importance in testing seed and soil treatments for the control of root rot diseases of cereals, and in studying the comparative resistance and susceptibility of cereal varieties to root rots caused by species of *Helminthosporium* and *Fusarium*.

SUMMARY

For the last three years, carefully planned field experiments have been made to determine efficient and practical methods of artificially creating destructive attacks of root rot diseases caused by *Fusarium culmorum* (W. G. Sm.) Sacc. and *Helminthosporium sativum* P., K., and B. on cereals. Especial attention was given to the arrangement of the experiments, methods of planting, soil infestation, harvesting, and recording and analyzing root/rot experimental data.

The extent of disease was expressed as a disease rating, which represents the percentage of the total number of plants which were infected and also the degree of infection. Each year, during the course of the investigation, the disease rating in a series of plots of Marquis wheat was varied by employing various devices to introduce root-rotting fungi into the soil. In the final analysis of the results of each experiment the disease ratings of individual plots were correlated with the yields. The results are summarized in the form of correlation coefficients.

The values of the coefficients obtained were highly significant, and hence it was concluded that the disease rating is an accurate measure of the amount of root rot caused by *F. culmorum* and *H. sativum* on cereals. It was demonstrated that *Fusarium* and *Helminthosporium* root rot diseases have a marked detrimental effect on the yield of wheat.

Various methods have been employed to induce severe attacks of root rot in the field. Of those tested, the seed spore-suspension method of introducing the fungus into the soil was most satisfactory with *F. culmorum*. Significant increases in disease rating and significant reductions in yield were obtained wherever this method was employed. The method has distinct practical advantages for field work.

A combination of two methods, namely, the inoculation of seed with a suspension of conidia and the application of oat-hull inoculum to the soil, gave the most satisfactory results with *H. sativum*. All the methods studied so far have failed to give a real epidemic of *Helminthosporium* root rot.

The results have emphasized the value and importance of plot arrangement, and the application of statistical methods to the interpretation of the results of field experiments with rootrot diseases of cereals.

LITERATURE CITED

1. Bolley, H. L. Wheat: Soil troubles and seed deterioration, causes of soil sickness in wheat lands, possible methods of control, cropping methods with wheat. N. Dak. Agr. Exp. Sta. Bul. 107. 1913

2. Christensen, J. J. Studies on the parasitism of *Helminthosporium sativum*. Minn. Agr. Exp. Sta. Tech. Bul. 11. 1922.

3. Cordley, A. B. A footrot of wheat. Oregon Agr. Exp. Sta. 14th Ann. Rept. 66-67. 1902.

4. Dominion Laboratories of Plant Pathology (Western). Studies in Cereal Diseases. IX. Losses caused by diseases of cereals in Western Canada. Dom. of Can. Dept. Agr. Pamph. 152. n.s. 1933.

5. Fisher, R. A. and J. Wishart. The arrangement of field experiments and the statistical reduction of the results. Imp. Bur. of Soil Sci. Tech. Comm. No. 10. 1930.

6. ——————. Statistical methods for research workers. Ed. 3. Oliver and Boyd. Edinburgh and London. 1931.

7. Goulden, C.H. Modern methods of field experimentation. Sci. Agr. *11* : 681-701. 1931.

8. Greaney, F. J. and D. L. Bailey. Studies in Cereal Diseases. II. Root rots and foot rots of wheat in Manitoba. Dom. of Can. Dept. Agr. Bul. 85. n.s. 1927.

9. Henry, A. W. Root-rots of wheat. Minn. Agr. Exp. Sta. Tech. Bul. 22. 1924.

10. ——————. The natural microflora of the soil in relation to the foot-rot problem of wheat. Can. Journ. Res. *4* : 69-77. 1931.

11. McKinney, H. H. Influence of soil temperatures and moisture on infection of wheat seedlings by *Helminthosporium sativum*. Journ. Agr. Res. *26* : 195-218. 1923.

12. ——————. Foot-rot diseases of wheat in America. U.S.D.A. Dept. Bul. 1347. Wash. D.C. 1925.

13. Machacek, J. E., and F. J. Greaney. The effect of mechanical seed injury on the development of foot rot in cereals. Can. Journ. Res. *8* : 276-281. 1933.

14. Sallans, B. J. Methods of inoculation of wheat with *Helminthosporium sativum* P., K., and B. Sci. Agr. *13* : 515-527. 1933.

15. Sanford, G. B., and W. C. Broadfoot. Studies on the effects of other soil-inhabiting micro-organisms on the virulence of *Ophiobolus graminis* Sacc. Sci. Agr. *11* : 512-528. 1931.

16. Simmonds, P. M. Studies in Cereal Diseases. III. Seedling blight and foot-rots of oats caused by *Fusarium culmorum* (W. G. Sm.) Sacc. Dom. of Can. Dept. Agr. Bul. 105. n.s. 1928.

17. Stakman, Louise J. A *Helminthosporium* disease of wheat and rye. Minn. Agr. Exp. Sta. Bul. 191. 1920.

18. Stevens, F. L. The *Helminthosporium* footrot of wheat, with observations on the morphology of *Helminthosporium* and on the occurrence of saltation in the genus. III. Nat. Hist. Surv. Bul. 14. 77-185. 1922.

Résumé

Etudes sur le traitement des pourritures du pied des céréales causées par *Fusarium Culmorum* (W.G.Sm.) Sacc. et *Helminthosporium Sativum*, P. K. et B. I. Méthodes suivies en plein champ. F. J. Greaney et J. E. Machacek, Laboratoire fédéral des recherches sur la rouille, Winnipeg, Man.

En ces trois dernières années on a cherché, par des expériences dont le plan avait été soigneusement tracé, des moyens pratiques et efficaces de créer des attaques destructives des pourritures des racines, causées sur les céréales par *Fusarium culmorum* (Wm. G. Sm.) Sacc. et *Helminthosporium sativum* P. K., et B. Ceux qui étaient chargés de la conduite de ces expériences ont donné une attention toute spéciale à leur préparation, au mode de plantation, à l'infection du sol, à la récolte, ainsi qu'à l'enregistrement et à l'analyse des données expérimentales. La fréquence de la maladie a été exprimée sous forme d'indice, représentant le pourcentage du nombre total de plantes affectées ainsi que le degré d'infection. Chaque année, au cours de cette enquête, on a varié l'indice de la maladie dans une série de parcelles de blé Marquis en employant différents moyens pour introduire dans le sol les cryptogames qui causent la pourriture. Dans l'analyse finale des résultats de chaque expérience, les indices de maladie des parcelles séparées ont été reliés aux rendements. Les résultats sont résumés sous forme de coefficients de corrélation. Les valeurs des coefficients obtenus ont été très significatives et c'est pourquoi on a conclu que l'indice de la maladie est une mesure exacte de la quantité de pourriture causée par *F. culmorum* et *H. sativum* sur les céréales. Il a été démontré que les maladies *Fusarium* et *Helminthosporium* exercent un effet très nuisible sur le rendement du blé. Différents moyens ont été employés pour provoquer de graves attaques de la pourriture dans le champ. De tous ces moyens, celui qui s'est montré le plus satisfaisant pour le *F. culmorum* est le procédé qui consiste à introduire le cryptogame dans la terre au moyen d'une suspension de spores. Chaque fois qu'on a eu recours à ce moyen, on a obtenu un relèvement significatif de l'indice de la maladie et une réduction sensible de rendement. Ce procédé présente des avantages pratiques distincts pour les travaux en plein champ. Une combinaison de deux méthodes, savoir, l'inoculation de la semence avec une suspension de conidies et l'application d'inoculum de balle d'avoine au sol, a donné les résultats les plus satisfaisants en ce qui concerne *H. sativum*. Tous les moyens employés jusqu'ici n'ont pas réussi à provoquer une réelle épidémie de la pourriture *Helminthosporium*. Ces résultats ont fait ressortir l'utilité et l'importance de l'arrangement en parcelles et de l'application de la statistique à l'interprétation des résultats des expériences en plein air sur la pourriture du pied des céréales.

THE ECONOMIC ANNALIST

A REVIEW OF AGRICULTURAL BUSINESS PREPARED QUARTERLY BY THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA

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THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index number of wholesale prices in Canada receded from 72.0 in September to 71.4 in October. The index of vegetable products declined nearly 2 points while lesser recessions were registered in the indexes of fibres, textiles and textile products; wood, wood products and paper; chemicals and allied products. Gains were reported for animal products; iron and its products; non-ferrous metals, and non-metallic minerals. On the whole wholesale prices have been consistently above the level of 1933.

Retail Prices.—The index of retail prices, rents and costs of services advanced from 79.0 in September to 79.3 in October. The sub-index of food rose from 68.8 to 69.4. The fuel index advanced from 88 0 to 88.5 and that of rentals from 79.7 to 80 3. The latter index is of interest because it has been declining steadily since May, 1930. During the first nine months of 1934 the monthly index number of the value of retail sales has been below that of corresponding months in 1933 only in April and September.

Physical Volume of Business.—The index of the physical volume of business declined from 97.1 in September to 95.8 in October. Industrial production fell from 97.5 to 95 3. Mineral production rose from 132.7 to 141.9 chiefly on account of substantial gains in exports of zinc and copper and in shipments of gold. Output of silver, asbestos, nickel and lead was slightly lower, while coal production was barely maintained. The index of manufacturing fell from 99.5 in September to 94.6 in October. Flour production was lower but sugar production and tobacco releases were larger. Imports of crude petroleum, textiles and rubber were lower compared with the previous months. The forestry products' index advanced from 93.8 to 100.3 chiefly on account of the rise in production of newsprint. Exports of wood pulp, and shingles were higher but fewer planks and boards were shipped abroad. The index of iron and steel products was lower in October. The construction index was lower than in September although the number of building permits was greater. Production of electric power gained. Agricultural marketings were lower but storage holdings were higher than in September.

Agricultural Products.—Prices of agricultural products were on the whole lower than in September. The index, therefore, declined to 60.9. The index of prices of field products fell from 58.9 to 55.3, lower prices for grains and potatoes being largely responsible. The average price of No. 1 Manitoba Northern Wheat was 82.3 cents per bushel, basis Fort William and Port Arthur, in September, whereas in October the average price was 78.2 cents per bushel. Similarly prices of No. 2 C. W. oats fell from 45.7 to 41.5. No. 3 C. W. barley declined from 58.5 cents to 51.6 cents per bushel. Grain marketings were lower than in September. The index

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79 2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130 0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134 0	145.5	142.4	152.5	107 2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109 2	66.5	60.4	65 2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82 6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102 6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100 0	100.0
1927	97.7	102.1	99.9	105.7	98 4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86 6	82.3	70.0	102 9	99.2	109.5	108.0	103 0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1933									
Jan.	63.9	43.6	35.1	57.9	79.1	68.1	62 2	56.1	112.0
Feb.	63.6	43.0	36.0	54.7	78.4	67.0	60.0	76.5	127.6
Mar.	64.4	44.7	38.0	56.0	77.8	68.4	62.5	129 0	135.8
April	65.4	46.8	41.1	56.4	78.0	69.8	65.1	104.1	112.7
May	66.9	51.2	46.9	58.4	77.0	76.4	72.7	95.4	110.4
June	67.6	52.6	49.4	57.9	77.0	82.2	79.8	221 9	119.9
July	70.5	60.1	60.8	59.0	77.2	84.1	82.6	221.9	119.9
Aug.	69.4	57.0	54.9	60.5	78 6	89.8	89.5	197.2	114.2
Sept.	68.9	54.7	49.5	63.4	78.5	90.8	90 2	101.1	115.7
Oct.	67.9	51.4	44.6	62.8	77.9	88.2	87.4	70.5	112.7
Nov.	68.7	53.8	46.7	65.8	78.1	85.5	83.9	41.8	111.1
Dec.	69.0	53.3	45.3	66 6	78.4	86.2	85.1	30.7	107.6
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67 1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130 6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60 0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172 8	114.7
Sept.	72.0	61.3	58.9	65.3	79 0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55 3	70.4	79.3	95.8	95.3	61.2	128.3

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1931, p. 15.

2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1931, p. 33, and Monthly Mimeographs 1933 and 1934.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries, See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.
Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeographs 1933-1934.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

dropped from 139.0 to 57.9. The decline in receipts of wheat, barley and oats at the head of the lakes was particularly noticeable.

In the case of animal products the index rose from 65.3 to 70.4. This advance was due to higher prices for milk, eggs, hides, and skins which more than offset lower prices for cattle, hogs, and wool.

Marketings of live stock were very little below those in September, the index receding from 76.7 to 75.7. Cattle, calves and sheep were marketed in larger numbers but receipts of hogs were below those in the previous month.

Cold storage holdings advanced from 117.7 in September to 128.3 at the first of October. Supplies of eggs, butter, beef, pork and lard, cheese, mutton, veal and poultry increased.

The Outlook for 1935.*—Business conditions in Canada continued to improve in 1934. Physical volume of business was higher than in 1933 and wholesale prices advanced. Prices of farm products also showed some improvement and as a result the farmers' position is somewhat better than a year ago. Present indications lead to the belief that there will be further gradual improvement in 1935.

Foreign demand will continue to be affected by trade barrier tendencies. There are, however, indications of rising prices and increased purchasing power. The employment situation in Great Britain has improved although there has been a tendency during recent months for living costs to rise.

Wheat has been moving more rapidly from farms during the present crop year than was the case a year ago but prices are still low and demand has not risen as rapidly as was anticipated. A careful analysis of the wheat situation suggests that Canadian wheat growers would be well advised to refrain from expanding wheat acreage in 1935. There seems to be opportunity for increasing acreages of oats, barley, rye, buckwheat, flax, and corn since reserves of these commodities are comparatively low and feed requirements may be high.

In regard to live stock, prospects are that total supplies of commercial cattle will be larger than in 1934. Some improvement in prices for good to choice cattle in the early winter is anticipated. The export market in Great Britain is not expected to show any appreciable change, although the shortage in the United States may react favourably upon the cattle industry in Canada. There are prospects for a moderate increase in exports of bacon to the United Kingdom in 1935 and hog marketings will not vary greatly from those of 1934. The domestic market for hogs should be slightly better if the anticipated improvement in prices of beef cattle takes place.

The production of sheep in Western Canada has grown to some extent but in Eastern Canada there has been a decline. The demand for lambs has been very brisk and therefore resulted in improvement in the sheep raising industry. Prospective supplies for 1935 would appear to be adequate. The wool market opened very briskly but has declined to some extent in recent months. On the whole, however, it has been fairly satisfactory.

The outlook for both poultry and eggs is reported to be more favourable than in 1934 when improvement over the previous year was shown.

Milk production continued an upward trend, larger quantities being diverted to the fluid milk market and to the manufacture of creamery butter. An outstanding feature of 1934 was the continued decline in the production of cheese. Indications are that unless there is a sharp rise in the price level, income from dairy products is not likely to increase to any great extent in 1935.

Improvement in demand for fruits and vegetable would indicate that markets for these products will at least be maintained at, or slightly above, the 1934 level. The extent of injury to apple trees during the winter of 1933-34 amounting to 40-50 per cent in Ontario will continue to affect supplies. Production of other tree fruits will probably be maintained. Prospects are that there will be an increase in the proportion of small fruits and vegetables produced for processing.

*Based upon preliminary reports of committees engaged in preparing the Agricultural Situation. 1935.

THE COMBINE HARVESTER

E. G. Grest[1]

During the summer of 1931 the Economics Branch co-operating with the Canadian Pioneer Problems Committee, the University of Saskatchewan and the University of Alberta, made an extensive study of Farm Power in Saskatchewan and Alberta. The analysis of data relating to combine harvester costs is briefly reported in this article. The areas in which the data were obtained are Davidson, Craik, Maple Creek and Richmond in Saskatchewan and Irwine, Hilda, Foremost, Bow Island and Olds, Alberta.

The areas visited in the southern parts of the two Provinces were fairly well suited to the use of combines for harvesting the wheat crop. A total of 63 combines was found on the farms included in the survey, 56 of which were found on farms in the southern areas and 7 on the farms near Davidson, Saskatchewan. Comparison of the combine harvester with the binder or header and threshing methods of harvesting crops is not attempted. More complete information than that included in this study would be necessary for a proper comparison of these methods. In areas where climate, uniformity of soil and regularity of topography make conditions favourable for combining this method of harvesting will probably be popular and profitable but where the crop ripens late in the fall and ripens unevenly or where the weather is likely to be damp or wet during the harvesting season, the risks encountered in the use of the combine harvester are serious. The losses in some years will be so large that harvesting by this method will prove more costly than when binders or headers and threshing machines are used.

Costs of Operation and of Harvesting per Acre.—The costs of operating the combines for which data were obtained and the cost of harvesting a crop per acre, not including the hauling of grain, are shown in Table 1. The cash costs to operate the combines, including labour and power to pull them, were $144.80 for 15 and 16 foot machines and $120.50 for 10 and 12 foot machines for the year 1930. Despite having a larger cutting bar the 15-16 foot combine was operating at 20 cents per acre while for the 10-12 foot combine the cost was 16 cents per acre. The lower cost per acre for the smaller machines was due to a greater number of acres harvested, an average of 736 acres in comparison to 709 for the larger combines. Interest, depreciation and servicing charges were also higher for the larger machines and thus, total operating expenses per acre for the 15-16 foot size were 92 cents while that of the 10-12 foot size were 80 cents per acre. If the larger machines had harvested as much crop in proportion to their size as the smaller ones then the operating expenses of each would have been more nearly the same.

The cost of man labour per acre required to operate the combine and tractor and the cost of tractor power to pull the combine was found to be slightly higher for the smaller machines. More acres were harvested per hour with the larger units thus lowering the cost of man labour per acre. The cost of tractor power was also lower in the case of the larger combine because, in many cases, the same size of tractor was used to pull both sizes of machines. A two-plow tractor can pull a 10-12 foot combine satisfactorily on level ground but the three-plow tractor is more generally used. A 15-16 foot combine is often drawn by a three-plow tractor and nearly as often by a four-plow size. Therefore, when calculating the cost of tractor power to haul the combines the average rate for the three-plow tractors was used for the 10-12 foot combines and a rate equivalent to using a three-plow tractor half time and a four-plow tractor the balance of the time was used for the 15-16 foot machines.

The total costs of harvesting a crop in 1930 were $1,138.80 per combine for 15-16 foot machines and $1,164.30 per combine for 10-12 foot machines. Reduced to an acreage basis the cost for the larger machine was $1.61 per crop acre compared to

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TABLE 1.—COMBINE OPERATING COSTS AND COST OF COMBINING PER ACRE, DAVIDSON, SASK. AND SOUTHWESTERN SASK. AND SOUTHEASTERN ALBERTA, 1930 CROP

	Size of Combine			
	15′ to 16′		10′ to 12′	
Number of combines	48		15	
Average acres harvested 1930	709		736	
Average value $	1,736		1,624	
Average size of farm (acres of cropland)	729		669	
	Per combine	Per acre harvested	Per combine	Per acre harvested
	$	$		$
Gallons of fuel used		0 41		0.46
Cost of fuel		0 11		0.12
Gallons of cylinder oil		0.02		0 02
Cost of cylinder oil		0.03		0.02
Cost of grease		0.01		0.01
Cost of hired labour repairing		0 01		
Cost of parts		0.04		0.01
Total cash costs	144 8	0 20	120 5	0.16
Interest at 6 per cent	104 1	0 15	97.5	0.13
Depreciation	371.4	0.53	356 3	0 48
Hours servicing, overhauling	57 4	0 08	46 8	0.06
Value of servicing[1]	31 6	0 04	21 9	0 03
Total operating costs	651.9	0 92	596 2	0 80
Cost of two men to operate combine and tractor[1]	204 0	0 29	247 7	0 34
Cost of tractor power to pull combine[2]	282 9	0 40	320 4	0.44
Total cost to combine crop	1,138 8	1 61	1,164 3	1.58

$1.58 per acre for the smaller 10-12 foot combine. As stated before, the higher cost per acre for the 15-16 foot combines was due mostly to a smaller acreage handled per machine. If the large combines had been handling the same number of acres per foot of cutting bar as compared to the smaller ones then the cost of harvesting would probably have been 10-12 cents higher per acre for the small machines than that of the larger units.

Relation of Acres Harvested to Cost.—The combine harvester is a relatively expensive machine and, therefore, when a farmer purchases one he must have as many acres per year as possible in order to reduce the overhead costs of interest and depreciation due to obsolescence to a reasonable figure per acre. In most cases 700 acres or more for a 15-16 foot combine and 525 acres or more for a 10-12 foot combine must be harvested per year to obtain a reasonable cost per acre of crop harvested. When conditions are not particularly favourable for combining it might be necessary to plan on harvesting fewer acres per season to reduce the risk of loss to the standing crop due to early snow-storms even though the cost of harvesting per acre is increased. The data were sorted according to the acres harvested in 1930 and the resulting operating costs per acre and the total cost of harvesting per acre were obtained. These data are presented in Table 2.

It will be noticed that in both cases the difference in cost between the group having the lowest number of acres harvested and the middle group is very great but the difference between the middle group and the groups having the highest acreage harvested is small amounting to 12 cents per acre for the 15-16 foot combines and 23

[1]The man labour rate for servicing these combines was 53.35 cents per hour. This rate was used to calculate the cost of the operator's labour of the combine and the tractor.

[2]The tractor rate used for 16′ combines was $1.48 and $1.38 for the 12′ combines.

TABLE 2.—ACRES HARVESTED PER YEAR, TOTAL COST OF OPERATING COMBINES PER ACRE, AND TOTAL COST OF COMBINING A CROP PER YEAR

	Acres harvested					
	15'-16' combines			10'-12' combines		
	100-499	500-899	900-1340	75-374	375-674	675-1130
Number of combines	10	25	13	2	6	7
Acres harvested per combine	296	687	1,070	295	536	1,033
Acres cropland per farm	563	751	814	378	662	758
	$	$	$	$	$	$
Total cost of operating combine per acre	1.58	0.91	0.79	1.38	0.94	0.71
Cost per acre:						
2 men operating	0 29	0.29	0.29	0 34	0 34	0 34
Tractor power	0.40	0.40	0.40	0 44	0.44	0 44
Total cost of harvesting per acre of cropland	2.27	1 60	1.48	2.16	1.72	1 49

cents for the 10-12 foot combines. Therefore, up to 700 acres or somewhat over, the saving in increased acres harvested per combine is large for the 15-16 foot combines. The same condition holds true up to 525 acres for the 10-12 foot combines. In the higher acreage groups although the saving with increased acres harvested is still quite evident it is not nearly so marked and, in some areas, it may not be profitable to plan on harvesting more acres due to the increased risk of crop loss.

THE AGRICULTURAL SITUATION

Through the co-operation of the Department of Trade and Commerce and the Department of Agriculture, the second annual review of the Agricultural Situation will appear early in January. The purpose of this review is to bring into concise form all the known factors affecting the supply of and demand for agricultural products in both domestic and foreign markets. With this information as a basis, farmers may adapt production and marketing policies to changing economic conditions; extension workers will be provided with data upon which to plan their programs; administrative officers will be assisted in formulating policies regarding production and marketing; and those responsible for the advancement of information to farmers will be able to present a more unified point of view with respect to the immediate future and the longer trends in agricultural production.

The report will include an analysis of foreign demand and competition; the domestic situation and each of the more important farm products will be considered separately. In this way, a rather comprehensive survey of the whole situation is anticipated. It is believed that this service will become increasingly important in the work of both Federal and Provincial Departments of Agriculture. The Provincial Departments of Agriculture in Saskatchewan and Nova Scotia have during the past two years prepared Outlook reports for distribution to farmers in their respective provinces and it is hoped that such policies may be possible in other provinces as well so that the farmer will be supplied with the best available economic information upon which to plan his business operations for 1935.

The report has been prepared by committees composed of officers from the Department of Trade and Commerce and the Department of Agriculture who will meet with representatives of the Provincial Departments of Agriculture and Agricultural Colleges in a three day session to be held in Ottawa, November 29th, 30th and December 1st at which the final draft will be completed. This bulletin will be distributed by the Publications Branch of the Department of Agriculture, Ottawa.

OBSERVATIONS ON THE ECONOMIC PROBLEMS OF GROWING FRESH VEGETABLES IN THE SOUTHERN INTERIOR OF BRITISH COLUMBIA[1]

A. E. RICHARDS[2]

Relatively high cost of production and the perishable nature of the product make vegetable growing one of the most hazardous of farming ventures. This is a general statement, but one which seems quite applicable to vegetable growing on the irrigated lands of the Southern Interior of British Columbia. In that area it has become a specialized type of farming and profitable returns have proven highly speculative. Markets for the crop have been transitory. Early commercial shipments which date back to the nineties and preceded fruit shipping on a commercial scale supplied mining camps in the Kootenay Valley and other mining districts in the province. The rapid populating of the prairies followed and the industry expanded to supply that market.

Following the war many of the mines were closed and that market restricted and now some observers hold the view that the British Columbia grower is gradually losing his command of the prairie market. There was a time when vegetable growing on the western prairies of Canada was not seriously considered as a commercial enterprise. By selection and improvement, varieties adaptable to the prairie growing season are now being produced in quantity and it is claimed by interested authorities that the three prairie provinces are rapidly moving towards a self sustaining position in respect to certain vegetables. Movement is reported of a number of growers of vegetables from the higher priced lands of the Okanagan Valley in British Columbia to irrigated prairie lands in the neighborhood of cities and towns in Southern Alberta. The statement is also made that British Columbia vegetable growers must look more and more to an off-season market on the prairie. While the local supply is in season it commands the market and the preference. It is placed on the prairie city markets in a fresher condition and without the handicap of a long transportation haul. There is another supply factor which may be taken into consideration. Due to the low price of grain it has been stated that a number of prairie farmers have turned their attention to vegetable production as a side line and undoubtedly they are growing more vegetables to-day for home use than in former years.

On the other hand the growing of vegetables on the prairies is precarious due to weather conditions. The Southern Interior of British Columbia has a more reliable and a longer growing season which enables the product of that area to be placed on the market before and after local supplies are available. Storage facilities in the Okanagan Valley also enable the vegetable growers to extend the marketing period considerably beyond the usual growing season.

A study of importation statistics shows that the United States still provides a large proportion of the prairie cities' vegetable supplies, a great deal of it being sold in direct competition with British Columbia products at a time when they are in season. The British Columbia growers are displacing the imported products no doubt to a certain extent, as production figures show that supplies and movement of tonnage to the prairie have been maintained over the past few years. While there has been a dropping off in the movement from British Columbia of some kinds of prairie grown vegetables, there has been an increase in certain other vegetables not commonly grown on the prairie lands. These include asparagus, peppers, eggplant, citron and cantaloupes.

The total vegetable acreage in the Interior of British Columbia has averaged 9,146 acres in the last ten years. During that period 1926 was the peak year with 10,303 acres. For 1934, an area of 8,194 acres was reported. The average annual

[1] This article is based on interviews and observations during the writer's visit to the Okanagan Valley and is presented as the popular view rather than a subject of research.
[2] Agricultural Economist, Economics Branch, Department of Agriculture, Ottawa.

value for four years 1927-1930 of the vegetable crop in the Interior of British Columbia was estimated at $1,501,980. Of this the cannery vegetable crops accounted for about one-fifth.

Table 1 shows the production of seven vegetables including tomatoes and cantaloupes during the last five years in the Interior of British Columbia.

TABLE 1.—PRODUCTION OF VEGETABLES IN THE SOUTHERN INTERIOR OF BRITISH COLUMBIA 1929-33*

Year	Semi-ripe tomatoes	Cannery tomatoes	Lettuce	Cucumbers	Celery	Onions	Cantaloupes	Potatoes
	crates	tons	pkgs.	pkgs.	tons	tons	crates	tons
1929	292,285	18,994	28,599	175,079	1,044	10,938	10,000	6,983
1930	264,894	25,582	12,908	138,697	826	8,720	13,050	6,170
1931	347,530	8,371	19,378	175,271	959	10,681	11,537	7,486
1932	294,860	8,939	20,587	96,947	782	13,089	20,756	4,958
1933	371,672	13,435	13,406	122,779	1,047	10,184	30,239	8,460

*Statistics from British Columbia Department of Agriculture, Vernon, B.C.

Out of the 8,194 acres estimated to be planted to vegetables in the 1934 season, 6,541 acres or 80% include those named in the Table 1. This table indicates that production although variable has not dropped to any appreciable extent during the last five years. Available statistics showing car arrivals at various prairie points do not differentiate between Interior of British Columbia and the Lower Mainland shipments. The whole of British Columbia is included in the one classification and it shows that shipments from the province have not been reduced as would be expected with growing competition from prairie vegetables. That British Columbia vegetables are displacing importations seems a reasonable conclusion which is further exemplified in Table 2.

TABLE 2.—ARRIVALS OF CAR LOADS OF VEGETABLES AT CITIES IN WESTERN CANADA FROM BRITISH COLUMBIA AND UNITED STATES 1931-33*

	Calgary		Edmonton		Regina		Winnipeg	
	B.C.	Imported	B.C.	Imported	B.C.	Imported	B.C.	Imported
	cars	cars	cars	cars	cars	cars	cars	cars
1931	473	221	374	172	182	167	145	603
1932	361	165	305	113	184	113	160	422
1933	501	136	352	84	122	93	215	352

*Statistics from Dominion Fruit Branch, Ottawa, cars of mixed fruit and vegetables included in items.

Average prices for the past eight years for a number of kinds of vegetables are given in Table 3. They show considerable variation from year to year with the usual decline from the peak years of 1928 and 1929. Prices improved somewhat in 1933 and this season to date are considered to be as good as last year.

In addition to competition for markets the original growers who are mainly of British origin from Eastern Canada and the British Isles are faced with competition n the production of their vegetable crops. This is largely a racial problem. A very large number of the growers at the present time and an increasing proportion are of other nationalities. With all members of the family in the field, working from daylight to dark, seven days a week, and with their different standard of living it is claimed that

TABLE 3.—AVERAGE F.O.B. PRICES FOR A NUMBER OF VEGETABLES AT INTERIOR OF BRITISH COLUMBIA SHIPPING POINTS, 1926-33*

—	Onions	Semi-ripe tomatoes	Cannery tomatoes	Cucumbers	Lettuce	Cantaloupes	Celery
	per ton $	per pkge. $	per ton $	per pkge. $	per crate $	per crate $	per lb. $
1926	20.00	1.00	16.50	0 45	2 40	1.75	0.02
1927	35.00	1.00	—	0.54	2 50	2 27	0 02¼
1928	40.00	0.65	—	0.65	1 80	2.50	0 02¼
1929	32.00	1.30	17.50	0 70	3 00	2 20	0.03½
1930	30 00	1 05	17.50	0 60	2 30	2.10	0 03¼
1931	20 00	0 60	—	0 40	1.80	1 65	0.03
1932	12.00	0 50	10 00	0 35	1.50	1 75	0.03
1933	15 00	0 60	10 00	0 35	1 25	1.75	0 03

*Statistics from British Columbia Department of Agriculture, Vernon, B.C.

they have displaced the original grower or forced him for economic reasons to rent his land. Although a number of the original settlers are endeavouring to hold their homes and holdings established in the growing of vegetables they cannot adjust themselves to the competitive standards and habits of living. The situation becomes a sociological problem of grave importance to the permanent welfare of the Valley.

Basis of sale.—Most of the vegetable crop is sold for cash with payment within two weeks from time of delivery. As a general rule the foreigner does not understand the complexities of the market. He does not comprehend pooling and waiting for returns and is willing to accept less for cash. Straight purchase has, therefore, become the general practice among independent as well as co-operative shipping houses. As there are usually more marketable vegetables offered than can be marketed, price cutting and consigning come into play, all of which bring about market instability. The perishable nature of the product aggravates the problem and it is frequently rushed on to an already over-stocked market. This results in a further break in price and often loss to the grower. Some growers complain of the activities of certain shippers who, on an expected rising market, act as dealers and buy at a firm price with a chance for profit. When the market tends to swing downward they become agents operating on a commission basis and leave chance for loss to the grower.

A considerable proportion of the vegetable crop is moved to market centres in mixed carloads containing fruit and some vegetables. The complaint is frequently heard among growers that their vegetables are used as "loss leaders" to make contacts with the trade at receiving centres and to help sell the fruit.

System of Land Tenure.—The original growers are land owners. Only a small proportion of the foreign population own land in the interior of British Columbia although the number is increasing. In the Ashcroft, Kamloops and Vernon areas vegetable growing is largely on a cash rental basis. In the Kelowna district about 70% is on a share basis and 30% cash rented. Under this crop-share plan the owner provides land and water, pays all taxes, does all horse work, supplies one-half the seed or plants and sacks together with 50% of fertilizer and cut worm poison. The land owner supplies the tenant with a house to live in. In hauling manure the tenant supplies help. The tenant plants, cultivates and harvests the crop. The crop itself or the proceeds of the crop are shared by owner and tenant on a fifty-fifty basis.

In the cash rental districts the tenants are largely of Chinese origin. The landlord receives a rental of $10 to $15 per acre and in certain districts the renter pays an additional charge of $5 or $6 per acre for water to irrigate his land. In the Ashcroft district the ranchers are few in number but their land holdings are large. They are

nearly all cattlemen, with irrigated hay land on the flats under private irrigation systems. The renter fits into the ranch organization. He irrigates the hay land and grows vegetables as a cleaning crop in a crop rotation on the older stands of alfalfa.

Size of Holdings and Hired Labour.—The size of holdings of specialized vegetable growers vary with an average of about ten acres per holding. Several vegetables are usually grown in combination with one or two kinds as major crops. Four acres form a one man unit of onion production for the tenant with additional help at thinning and harvesting. Eight acres is regarded as a one man unit for tomatoes on the rented lands. On a ten acre block of tomatoes a man and his wife work all through the season with one helper. During planting and harvesting additional help is hired. On a ten acre block of onions a man and his wife do practically all the work themselves. Such industry means long hours of work every day in the week without relaxation or social recreation.

INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS

Three Canadians—Dr. J. E. Lattimer, Macdonald College, P.Q., Dr. W. Allen, University of Saskatchewan and Dr. T. W. Grindley, Dominion Bureau of Statistics—attended the Third International Conference of Agricultural Economists at Bad Eilsen, Germany from August 26 to September 1. The meetings were held at a quiet resort situated in the Weser valley of Lower Saxony. While the immediate vicinity of Bad Eilsen is pleasantly hilly and wooded, the surrounding country forms one of the finest farming regions of Germany. Well-directed trips through the farms gave the delegates an opportunity to become acquainted with the methods of husbandry. The intensive cropping and the strip-farming which has continued since the Middle Ages were the most interesting features to overseas visitors.

The objective of the Conference was to provide an opportunity for discussing fully and frankly the many problems that have arisen out of the world agricultural crisis, the various means taken to meet them and the possible ways for definitely overcoming them through national action and international co-operation. In the formal discussions but particularly outside the conference room, the problems of agriculture were thoroughly covered. The means of correction were found by the speakers to lie almost entirely within the field of national action and the methods of correction differed so greatly among the countries that the benefits of discussion were somewhat diminished. "International co-operation" in the discussions was practically limited to the opening remarks of the President, who sponsored the gospel of more trade and more credit, based on more faith between nations. The discussion, however, quickly turned to practicality and nationalism. Striving for independence—agricultural, commercial and financial—most countries of the world have gone far into the field of uneconomic production. Control policies are being formulated everywhere to build up the nations within their borders and with consequent depreciating influences on world trade. This, plainly enough, is a situation which Canada must appreciate; our hope for the present and at least for the immediate future lies in Empire trade and, to a lesser extent, in trade with the United States and South America.

The Conference proper was presided over by the President, Mr. L. K. Elmhirst, ably supported by the Vice-presidents, Dr. Sering, Deutches Forschungsinstitut Für Agrar—und Siedlungswesin, Berlin and Dr. Warren of Cornell University, Ithaca, N.Y. Dr. Zorner of Berlin and J. P. Maxton of Oxford also did a great deal to make the Conference a success. The language difficulty was well handled through concurrent translation. Those not able to understand the language in which a paper was being presented could hear the paper in their native tongue merely be donning the ear-'phones.

REGULATION OF MILK SUPPLIED IN SASKATCHEWAN

Control measures affecting the milk industry are now operative in five of the nine provinces in Canada. Manitoba was the first province to have such regulation, an act being passed in 1932 to bring the milk supply of Winnipeg under the Public Utilities Commission. In Alberta, similar legislation went into effect in August, 1933, controlling milk in Calgary and Edmonton. A separate body to regulate milk in Quebec was set up in April 1933, and in the winter of 1933-34 a milk commission was appointed to supervise the distribution of milk throughout the whole province. A milk control act was passed in the 1933-34 legislative session of Ontario. A separate body, having jurisdiction over the whole province, was appointed to supervise the act. Legislation for milk control in Saskatchewan was also provided at the 1933-34 session of the legislature of that province.

The regulation of milk supplies in Saskatchewan comes under Part III of the Local Government Board Act. The Act was extended to include this legislation as a result of the recommendations made by the Saskatchewan Milk Enquiry Commission, 1933[1]. The Act gives the Local Government Board jurisdiction upon its own initiative or upon complaint in writing, to enquire into any matter relating to the production, supply, distribution or sale of milk. After such enquiry if the board sees fit it may make such regulations or orders as it deems necessary.

The Board may prescribe the area in which regulations shall have effect and may require all persons who distribute, process, or sell milk in any such area to be authorized to do so. The Board may also classify milk producers, processors and distributors and may establish from time to time temporary schedules of prices at which milk shall be supplied by the respective classes. The Board may require distributors to keep adequate records and to report their operations to the Board when asked.

To offset the cost of administration of the regulation of milk supplies the Board may assess producers and distributors in any prescribed area for such sums as may be necessary. If deemed expedient the board may license either producers or processors or distributors and charge a reasonable fee for the licence. Licences may be refused, cancelled or suspended.

The Board also has the powers of inspection and examination. It may enter any building or plant, summon witnesses and require the production of records and accounts.

Every person who violates any regulations of the board is liable to a fine not exceeding $100 per day for each day during which the offence continues.

The board may recommend the appointment of an administrator and such inspectors and other staff as may be necessary to carry out the provisions for the regulation of milk supplies.

The first milk administrative order was issued for Moose Jaw on July 21, 1934. One for Regina followed soon after. Both went into effect on August 1. Order number three was made for Prince Albert, while on October 27, Yorkton, and on October 29, Saskatoon, milk supplies came under regulation.

Complaints in writing from the producers, distributors or both were received by the board from each of the five places mentioned above. The board held enquiries and decided that temporary schedules of prices should be established.

The price established for milk delivered by the producer on August 1, was 45 cents per pound butter-fat in both Regina and Moose Jaw. On October 1, this price was raised to 50 cents in the case of Regina and 52 cents in Moose Jaw. From November 1 to December 31 Saskatoon producers will receive 48 cents per pound butter-fat and Yorkton producers will get $1.55½ per hundred pounds for 3.5 milk with 3 cents added or deducted for each one-tenth above or below 3.5 per cent.

[1] The reader is referred to the Economic Annalist, Volume IV, No. 2, page 19, for a brief review of the recommendations made.

Consumers in Regina, Moose Jaw and Saskatoon pay 10 cents a quart for milk from the distributors. In Yorkton they pay 8 cents per quart. Stores can buy bottled milk at one cent less than this figure and take one cent per bottle spread, except in Regina where the price of bottled milk to stores was raised to 10 cents and to consumers through stores to 11 cents per quart. Hotels and like institutions buying milk in bulk pay 32 cents pér gallon in Regina, Moose Jaw and Saskatoon and 26 cents per gallon in Yorkton. Prices for chocolate milk, vi-co, and the various grades of cream are also set for the consumers, stores and hotels. Milk to be separated for the fluid cream trade is paid for at a lower rate to the producer.

Licences are required in each city for all persons who distribute and sell milk. The fee for a licence is three dollars in Regina, Moose Jaw and Saskatoon and one dollar in Yorkton. Producers have not been licensed except in so far as they are distributors.

Payment of a fee of 4/10 of a cent for each pound of butter-fat delivered is required of every producer and 4/10 for each pound sold of every distributor in each of the three larger cities. In Yorkton 1½ cent per hundred pounds of milk is assessed to both distributors and producers.

The distributors in each city must pay the producers on the 20th and 5th of each month. Distributors deduct the fee from the producers' returns and pay the amount to the board together with the fee assessed on them.

Dr. G. H. S. Barton discussed the marketing of farm products in an address delivered before the members of Canadian Society of Technical Agriculturists at a dinner held in the Chateau Laurier, Ottawa, on November 13th. In the course of his address, Dr. Barton pointed out the need for educational work in respect to marketing. These problems, he stated, should be studied by the research method of approach. He gave as a solution to our problem of "abundance" the stimulation of home consumption. Consumption, he said, has been taken for granted in the past; it should now be examined. To stimulate home consumption, producers must supply consumers that which will appeal to them, and products must be of the very best quality. Service to the consumer should become the motto.

Reports of creamery butter production for the nine months ending September 30th, 1934, show a total of 189,473,377 pounds manufactured as compared to 177,988,-052 pounds for the same period of 1933, an increase of nearly 11½ million pounds or 6.45%. All provinces report increases except Prince Edward Island and Nova Scotia. Should creamery butter production be maintained at the increased rate of production of the first nine months, total production for 1934 will show a further increase over the five-year average 1929-33 than was recorded for 1933, which was 6.6%.

The Dominion Marketing Board appointed under the Natural Products Marketing Act, 1934, has approved of five schemes which are now in operation. The first one approved was that for tree fruits produced in certain sections of British Columbia. The second was a scheme to regulate the marketing of apples and pears for export. The third applies to the export to the United States of red cedar shingles, produced in British Columbia. The fourth regulates the marketing of dry salt herring and dry salt salmon produced in British Columbia and the fifth is to control the marketing of flue-cured tobacco in the province of Ontario.

A meeting of the Joint Committee on Economics composed of representatives of the Dominion and Ontario Department of Agriculture and the Department of Economics at the Ontario Agricultural College, and Queens, Toronto and Western Universities was held in Toronto, November 3rd. Research work was reviewed and plans for new work outlined.

PRICE POLICIES

Price cutting is the cause of much complaint among growers and shippers of farm products and constitutes a very difficult problem due to the fact that it may arise from a variety of causes.

In the first place price cutting may be regarded as a form of competition. It is particularly apt to occur in seasons when the existence of an over-supply is known and shippers become panic-stricken in anticipating a sharp fall in prices. It may also occur when there are two or more types of growers, one of which has a lower standard of living than the others. This is particularly true where a large proportion of the work can be done by hand and the operators are willing to accept low prices. It is frequently used by dealers as a means of securing new trade contacts and in increasing sales through established outlets. It may also be used as an advertising device. Very often price cutting arises through the necessity of growers having to sell out a crop early in the season in order that they may secure cash to liquidate debts. Sometimes price cutting takes the form of a rebate. It should be recognized, however, that lower quotations may result from more efficient production or marketing and for this reason price policies must be closely studied in order that the real effect may be understood.

An example of the first mentioned type is found in the case of a large supply which dealers seek to move quickly so that they may dispose of their holdings before the real break in prices occurs. Very often such action precipitates the very situation which it was sought to avoid.

An example of the second type may be found where white growers compete with growers of certain other racial types. The vegetable grower who is not of white origin may utilize hand labour almost exclusively, work long hours, and accept a relatively small cash payment rather than assume the risk of carrying the crop for a longer period so as to adjust supplies more nearly to demand. The offer of an attractive price as a means of securing new outlets is well known and needs little explanation. Sometimes it may happen that brokers may wire for quotations. Inevitably one will be lower than the rest and the broker may then wire another dealer to the effect that the product may be bought at a price below this quotation. The second dealer may then assume that his original quotation was too high and will either quote at the lowest figure previously offered or cut under it. In this way the price is lowered.

An example of price cutting as a means of advertising is found in the "leader" policy adopted by certain stores, in which case a product may be sold below cost in order that customers may be attracted to the stores and in addition to purchasing the leader, will be persuaded to buy products displayed at regular prices.

The relation of "distress selling" to price cutting is pretty well established. A shipper or grower who is in need of cash very frequently will under-quote the generally recognized price in order to secure a quick turnover and satisfy his creditors. One example of the rebate system may be found in the case of a direct purchase by a wholesale receiver from a shipper. The wholesaler may request that the price be lower by the amount of the brokerage charge which has been avoided. This places him in a position to under-quote his competitor and results in lower values for the shipper.

The foregoing illustrations all deal with price cutting among firms assumed to possess equal efficiency. There are, however, circumstances under which competitive conditions result in lower prices because of increased efficiency. A new area of very fertile land may be brought into cultivation and growers in that area may be able to undersell established producers in their own markets. A new and cheaper method of processing may be introduced or an established business may be reorganized so that operating expenses are reduced, and as a result the business may be able to undersell competitors and still make an adequate return to stockholders. Consumers and growers, too, are entitled to the benefits of such efficient service.

From this brief outline of price cutting methods it will be apparent that there is ample room for abuses to creep into business policies. A rigid price is apt to be even less satisfactory because a rigid price which is too low fails to call forth the necessary supply and to stimulate efficient performance of marketing services. Contrariwise a rigid price which is too high may for a time enable excessive profits, but eventually stimulates a surplus. Most farmers' business organizations are obliged to adjust supply to demand as well as can be done, and to market annual supplies of the product excluding a reasonable carryover within the annual cycle of production and consumption. Efforts of independent handlers to stabilize prices through gentlemen's agreements are difficult to enforce and may be questioned on legal grounds. Adjustment of supply to demand is not a simple process because free competition does not always exist. Farmers who are widely scattered find it difficult to make such adjustments unless some central marketing agency operates in their interest. The alternative is to set up legal machinery and safeguards under which growers and dealers in farm products may effect a measure of regulation of marketing without injuring the consumer.

ECONOMIC LITERATURE

MacKintosh, W. A. Canadian Frontiers of Settlement. Volume 1, Prairie Settlement, the Geographic Setting. The MacMillan Company of Canada, Limited, 1934.

This book is the first of nine volumes on the Canadian Frontiers of Settlement. The volumes present some of the results of research carried on by the Canadian Pioneer Problems Committee since its organization in 1929. Dr. Isiah Bowman, Director of the American Geographical Society of New York, has guided the project from the outset, and the Social Science Research Council has, by generous grants of funds, made possible the five-year programme of research and the publication of this and the other eight volumes.

This volume outlines the Geographic setting of Prairie Settlement. The first four chapters deal with the land and the climate, agricultural exploration, railways and settlement, and the spread of settlement.

The settler coming to the Canadian grasslands was confronted with many unfamiliar problems. Frost in the north and drought in the south made crops precarious. Adequate transportation was lacking. In the majority of cases the settler's traditional knowledge was not suited to grappling with the problems which confronted him. Early explorers namely, Captain John Palliser, Sir John Richardson, Dr. Richard King, S. J. Dawson and Professor John Macoun, made studies of the frontier and gave opinions as to the desirability of settlement and probable extent of suitable agricultural land. The need of some market or conveyance for grain was stressed by Sir John Richardson.

In 1878 the first railway reached Winnipeg. It connected the Red River Settlement with St. Paul and Chicago. By 1883, the Canadian Pacific Railway stretched north of the Great Lakes to link Winnipeg with Eastern Canada. In 1885 the first transcontinental line was completed from coast to coast. From a series of maps presented in the book it appears that the railways followed the settler rather than preceded him. For the most part railways now have been built up to the ten-mile limit, that is to say the settler in general is within a ten-mile radius of a railway point.

In Chapters 5 to 8 the various sub-regions of the Canadian interior plain are outlined. The author discusses the climate, topography, agriculture and density of settlement in these sub-regions. Physiographically the interior plain of North America forms one region. The region, however, is subdivided into a number of sub-regions differing from one another in topography, climate, vegetation, and soil. The Canadian section may be divided into five sub-regions: (1) the Red River Valley, (2) the Park Belt, (3) the Prairie Plains, or semi-arid belt, (4) the Forest Belt, and (5) the Peace River Valley.

The Red River Valley has been settled longer than any other part of the Canadian Plains. Its climate and soils are well known and understood. Its problems are not pioneer problems but those of maturity. With changes in land utilization changes in rural population may occur. Increases are somewhat dependent upon a larger market being afforded by the urban area of Winnipeg. With the exception of the Red River Valley, the Park Belt is the most densely settled area of the western plains. Practically all townships in it have a rural population density of five to ten persons or greater. Since the size of farm throughout the Park Belt is increasing as in other areas, it is unlikely that the density of rural population here will increase greatly, except in foreign language settlements.

An especial problem in regard to permanency of settlement exists in the dry belt of the prairie plains area. Permanent settlement of the dry belt will probably be advanced in three ways. First as markets expand some increase in the irrigated areas may be expected. Secondly, areas less favoured in topography and soil but better watered will turn more strongly to grazing. Thirdly, grain growing with improved rotations and improved tillage, larger enterprises with sufficient capital to average the good years with the bad, will use the better soils and the better topography.

Settlement in the wooded area has been difficult and slow. The cost of clearing the land has been a powerful deterrent. In part, the slowness with which railways came to serve the sparse settlements of the Forest Belt was an obstacle to further settlement. Over the whole transitional soil belt from Manitoba to Alberta from 33 to 70% of the land is classed as unsuitable for cultivation. On the basis of this evidence one can predict that the density of settlement in these areas will be low, and that the problem of maintaining adequate transportation, governmental, and social services for the settlements will be correspondingly difficult.

The Peace River Valley is the area in which settlement has been most active during the past decade. The southern boundary of the Peace River Valley is about 54° and the land is being tilled north of 58°. Markets are distant, Grand Prairie being 407 miles from Edmonton; 1,178 miles from Vancouver, and 2,555 miles from Montreal, its two ocean ports. Settlement in the Peace River Valley is so recent and so immature that the ultimate distribution of population is not apparent. It may be predicted, however, that unless restricted by transportation difficulties, population will attain higher densities on the parkland soils.

Chapter 9, deals with climatic variability of the western plains. Over the greatest part of the region it is necessary to conserve moisture, and in considerable areas early maturing grain and speed in farm operations are necessary to avoid the penalties of a short growing season. The margin of safety in both cases is comparatively narrow. The wheat farmer in Western Canada is engaged in a business subject to unusually sharp fluctuations, imposed on it in greater or less degree by pronounced variations in rainfall and the other climatic conditions of wheat growing, and by the necessity of competing in a far distant world market for the sale of a raw material.

Chapter 10, the final chapter, is devoted to a discourse on the probable limits of settlement. Under favourable economic conditions land in farms may be expected to increase by 20 million to 30 million acres, depending upon the proportion of woodland included. The extension of the agricultural area, the substitution of "mixed farming" for grain farming, and the high rate of natural increase among the non-Anglo-Saxon population are factors favourable to an increase in rural population. The extension of mechanization and the increasing size of farms are factors limiting such an increase. Markets for the products of mixed farming are not likely to be extended rapidly; the area of suitable land open for settlement is not large; and the size of farms on the Canadian plains is still considerably less than that in corresponding parts of the plains in the United States. For these reasons, it is likely that further increases in the rural population of the Prairie Provinces will be small, and that in the near future decline may succeed increase.

NOTES

The American Farm Economics Association will hold its twenty-fifth Annual meeting at Chicago, December 26th to 29th inclusive. The American Economic Association and other national associations will meet at the same time. Dr. J. F. Booth, Economics Branch, will present a paper on Measures of Relief and Rehabilitation in Canada and Dr. W. C. Hopper will discuss marketing agreements. Dr. Wm. Allen, University of Saskatchewan, will discuss problems relating to debt adjustment.

The Canadian Society of Agricultural Economics held a local meeting in the C. S. T. A. Rooms, Ottawa, on the evening of November 28th. Dr. J. E. Lattimer, Macdonald College and Dr. T. W. Grindley, Dominion Bureau of Statistics, who recently attended the third International Conference of Agricultural Economists discussed agricultural conditions and policies in Europe. Dr. W. V. Longley, president of the Society, presided.

The organization of the Economics Branch of the Department of Agriculture' Ottawa, has recently been altered to provide for separate Divisions of Farm Management and Marketing. The activities of the Branch will continue to include other work in agricultural economics.

Mr. J. Coke, who since 1930 has acted as Assistant Commissioner of the Agricultural Economics Branch, will also assume the position of Chief, Division of Farm Management. Mr. Coke came to the Economics Branch from the Ontario Agricultural College where he had for some years been a member of the staff of the Economics Department.

Records from about 90 creamery operators were obtained in a recent survey of butter plants in the Prairie Provinces. Tabulation and analysis work on these records will be carried on this winter. In the conduct of this study the Provincial Departments of Agriculture, and the Economics Departments of the Universities of Manitoba and Alberta co-operated with the Dominion Department of Agriculture, Dairy and Economics Branches.

Dr. W. C. Hopper, who was for some years on the staff of the Dominion Experimental Farms but who left to take graduate work in Economics at Cornell University and later to accept a position at Washington, was recently appointed Chief of the Division of Marketing, Economics Branch, Ottawa. Dr. Hopper will also act as Secretary of the Dominion Marketing Board.

Mr. W. F. Chown recently joined the staff of the Economics Branch as Accountant Examiner. Mr. Chown is a graduate of Queens University. He was also for a time student at the Ontario Agricultural College and more recently obtained the degree of Chartered Accountant and admission to the Institute of Chartered Accountants. His work with the Department will be in the field of business and cost analysis.

Through a co-operative arrangement with the Dominion Marketing Board the staff of the Economics Branch will be used by the Board for research and general service when required. Assistance has already been given in connection with two schemes.

The provisional estimate of Canada's 1934 wheat crop is placed at 275,252,000 bushels by the Dominion Bureau of Statistics. Production for 1933 was 269,729,000 bushels. In the Prairie Provinces the provisional estimate of the 1934 wheat crop is 263,000,000 in comparison to a production of 250,841,000 in 1933.

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SOIL SURVEY: A BASIS FOR LAND UTILIZATION IN BRITISH COLUMBIA[1]

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In order that one may get a clear picture of the use of the soil survey as a basis for determining the proper utilization of land in British Columbia, it may perhaps be wise at the outset to recall the climatic conditions and topographic features as they exist in the Province. British Columbia is a region of extremes. Its numerous mountain ranges extend for the most part in a north-westerly and south-easterly direction. Agricultural lands are to be found at elevations varying from sea level to 4,000 feet and over. The mountain ranges and prevailing winds exert a tremendous influence on both the amount and distribution of precipitation. Annual rainfall varies from less than 10 inches in some regions to 200 inches and more at other points. The differences are great, even within a few miles, at approximately the same elevation. In regions of low precipitation the rainfall is fairly well distributed throughout the year, while in regions of a higher fall, 30 inches or over, it occurs largely during the winter months with relatively little throughout the growing season. Shallow and deep phases of glacial, volcanic, alluvial and organic soils are found in practically all these climatic regions.

The various factors enumerated above exert a tremendous influence not only on crop production, but on the soil itself. In the conduct of a soil survey the logical procedure is obviously to associate these factors with the survey so far as is possible. Since the soil profile in the case of a mature soil presents an excellent picture of the soil-climate interrelationships, it appears highly advisable to base the survey on a profile study. Such a procedure insures a better understanding of soil characters and peculiarities in any climatic region, and is therefore particularly desirable in the case of high-priced lands or those devoted to specialized crops.

For practical purposes many extensive areas are being grouped without the use of a detailed survey. For instance, some twelve years ago the Provincial Department of Lands undertook a forest survey which involved among other things the mapping of areas suitable only for reforestation. A soil surveyor accompanied the party, and as a result in many regions the boundaries between forestry and agricultural lands have been defined, some 12,000,000 acres having already been definitely prescribed as forest

[1] Presented at the annual meeting of the Soils Group of the C.S.T.A. at Macdonald College, P.Q., June 26 and 27, 1934.

[2] Associate Professor of Agronomy, University of British Columbia and Officer in Charge, Soil Survey respectively.

reserves. This work is continuing. It is hoped that a similar broad general type of survey may be extended at the first opportunity into the agricultural field itself in such a way as to map the areas which should be reserved for grazing purposes. Thus we would have our forest regions, grazing areas, and cultivatable lands defined.

The official designation of the foregoing areas, based on a general survey associated with a detailed soil survey of arable lands, will obviate certain serious difficulties with respect to logical development of rural British Columbia. First, forest and grazing areas will be preserved to advantage in that settlers will not be permitted to "prove up" on relatively small acreages suitable for general agriculture which may lie within typically grazing or forest regions. The former obviously must be reserved to provide winter forage for range stock. Second, under existing conditions hundreds of families occupy lands which are too poor or too small in area to return a fair living. Revenue arising from such agriculture will not support schools, roads, and other public services necessary for a desirable standard of citizenship. Utilization of submarginal lands is an outstanding illustration of our present misuse of land. Third, the detailed survey will define arable lands in both settled and unsettled districts and will bring forcibly to our attention the numerous soil problems which are now existent or may become so with settlement. Some of these will be referred to more or less generally when giving consideration to the detailed soil survey.

SOIL SURVEYS IN BRITISH COLUMBIA

While forest surveys have been under way for some years, the detailed soil survey was instituted for the first time in British Columbia in 1931. Special demands have so far determined the districts surveyed and to date they have been confined entirely to semi-arid regions. Soil maps of eight different districts have been prepared covering over 65,000 acres in all. Pits have been used almost exclusively for the study of soil profiles, and these, along with the extreme variation in the soil where agriculture is highly specialized, have necessitated a slow but accurate prosecution of the work. As familiarity with the soils of the region increases, not only may the number of pits required be considerably reduced and the rapidity of the work thereby appreciably increased, but also, the knowledge thus acquired may be projected and used to advantage in the subsequent survey of other areas. Thus it is believed that as the survey proceeds the acreage covered will be speeded up without any sacrifice in accuracy.

Progress in the conduct of the survey will be much more rapid, too, in humid regions where in the case of large areas, the soils are immature and show no profile characteristics. In such cases the soil auger will be sufficient for subsoil studies and will for specific reasons largely substitute for the pit on soil types where profiles are clearly defined.

We are asked on occasion why, for subsoil studies, an auger is not just as satisfactory as the digging of pits. It probably is when one is surveying an area devoid of any profile characteristics. When surveying regions wherein the soils have distinctive profiles, the pits are necessary in order that one may study the various horizons in detail and secure valuable information on soil-climate interrelationships. Through this procedure also, one is able to correlate soils, to some extent at least, with those of

the European countries where similar practices have been followed, and thereby benefit locally from the intensive study to which corresponding soils of Europe have been subjected. There are other points, of course, relative to the use of pits, but space does not permit their discussion on this occasion.

The surveys to date have been confined to areas already under cultivation or to those thought to have agricultural possibilities other than for grazing. In some districts already under irrigation, seepage presents serious difficulties; hence in the survey of areas for which irrigation is proposed, the surveyor gives particular attention to the possibility of its occurrence and probable control. While he is obviously unable to forecast control measures in all instances, his report will be invaluable in coping with the problem should it develop. The probability of alkali becoming a problem upon the addition of water also receives careful consideration.

Elevation, topography and relationship of arable lands to adjacent mountains are extremely important. Elevation may be a factor influencing soil type, but it at the same time determines the suitability for specific plant species. Topography is obviously often the lone factor determining the disposition of land. It has at the same time a tremendous influence not only on irrigation and irrigration problems, but also on ease of cultivation and cultural practices. The proximity, location and height of mountains exert such an influence on the adjacent arable lands, in many instances, that they must be given consideration in compiling the report. Thus, in the preparation of our soil maps mountains are indicated where necessary, contours are transferred to it when available, but unluckily a very small proportion of the Province has been surveyed topographically. If such data were available it would add immeasurably to the value of the map. We have felt it necessary in some instances to determine grades, transfer these to the soil map in per cent, and indicate direction of slope by means of arrows. This takes time of the field men which should otherwise be devoted to the soil survey itself. It is to be hoped that topographic maps may be available in the not too distant future.

USES OF THE SOIL SURVEY

Upon correlating survey findings with meteorological data, latitude and elevation, one is able to arrive at a reasonable conclusion as to the suitability of the soils for specific purposes. For instance, one can determine with some assurance whether or not a particular area is suitable for irrigation; whether or not there is likely to be a seepage problem; if so, whether or not it can be readily controlled. One irrigation district which has been surveyed showed 83.8% of the arable land to have no moisture holding capacity. Many of the orchards in this area disappeared following the drought of 1929, when the supply of irrigation water well nigh failed. These soils were coarse in texture, shallow and underlaid by sand, gravel and small boulders. They could be maintained in production providing unlimited supplies of water were available. In such a case, however, seepage would have to be controlled and heavy leaching losses taken into consideration, both of which would naturally involve additional expense.

We have soils and climates suitable for a great variety of specialized crops. Knowledge as to the possible extent of these areas is entirely

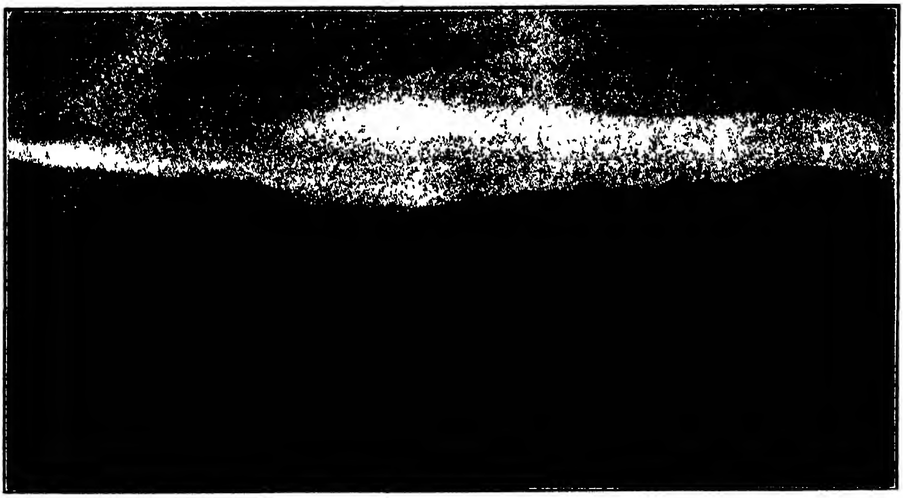

FIGURE 1. Orchard land in the foreground with grazing country in the distance. Vernon District British Columbia.

FIGURE 2. Black sandy loam, shallow phase; typical of many North Okanagan orchard soils, British Columbia.

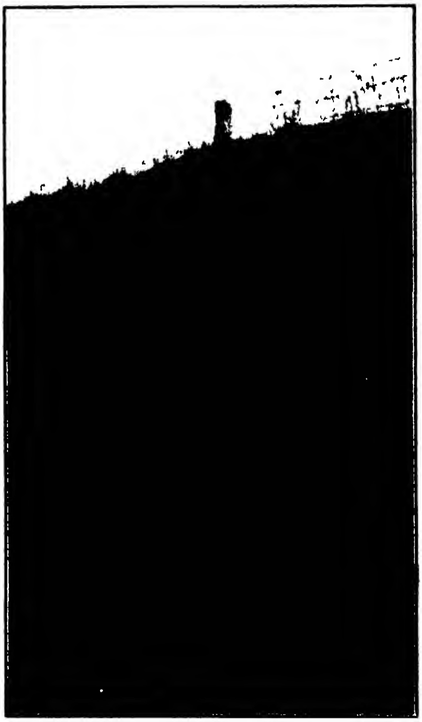

FIGURE 3. A heavy clay profile; typical of some North Okanagan soils, British Columbia.

empirical at the present time, but it is hoped that through the survey and supplementary studies one may be able, with a fair degree of accuracy, to estimate acreages in the various agricultural districts suited to each of the specialized crops which British Columbia is capable of producing. Or, on the other hand, one may simply derive from the survey report figures on acreage suitable for agricultural purposes in any district or region.

The survey and the chemical analyses associated therewith give one a lead as to some of the problems associated with certain soils, if they are not already known, and, through the mapping of types, the distribution of these problems. For instance, there is the problem of heavy leaching losses from some of the soils in humid regions, and there is the possibility of alkali developing in some other areas. Alkali is already recognized in some localities and the extent of these areas can be determined more economically in conjunction with the survey than at any other time.

Results obtained from fertilizer experiments during the past twenty years have served as valuable guides for the use of commercial manures, but we have not been able to make maximum use of the data, simply for the reason that we do not know the extent to which the results of each experiment are applicable A soil map would enable a much broader application to be made of data relating to fertilizers and would ensure a more accurate interpretation being placed on such data.

Much use is being made of the survey to date, but it must be remembered that the survey itself constitutes only the ground work as it were, and is not the end in itself in so far as either theoretical study or practical applications are concerned. If the findings are to be carried to a logical conclusion and the maximum value obtained therefrom, the soil map and associated data should be used as a basis for systematic study of the soil types mapped. Field and laboratory studies should be undertaken to ascertain how each of these types may be handled to best advantage, what procedures must be adopted to overcome weaknesses, how their strength may be utilized to best advantage, and for what specific types of agriculture they are best adapted. To date the surveys have not been used to any appreciable extent for such purposes, but it is our hope that this condition will be only temporary.

A soil survey is, in our opinion, fundamental to a planned and progressive policy for agricultural development along sound economic lines. The survey, we believe, has demonstrated its value in this regard, and already the practice of conducting such a survey before any extensive development work is undertaken, has been adopted. While the soil survey is not infallible, yet its utilization should eliminate the enormous agricultural waste which comes from attempts by courageous but misguided pioneers to develop farms in forest regions, upon range or upon submarginal lands in agricultural areas, and should reduce the number of disappointments with respect to the use of irrigation.

Our settlement policies, our fertilizer experiments, our general soil investigations and our studies on specific soil problems, all with an eye to a more profitable agriculture, should be based essentially on the soil survey. With this systematic organization our objective should be attained both economically and effectively.

No one can determine, or even estimate, the agricultural possibilities of British Columbia without a detailed knowledge of its soil resources. Since this knowledge can be obtained most effectively in conjunction with, or following the soil survey, it would appear to be highly desirable to give it a prominent place in any agricultural program.

Résumé

La classification des sols: une base pour l'utilisation des terres en Colombie-Britannique. D. G. Laird et C. C. Kelley, Université de la Colombie-Britannique, Vancouver, et le Ministère de l'Agriculture de la Colombie-Britannique, Victoria, C.-B.

Nous sommes d'avis que la classification des sols doit être une mesure préliminaire dans tout programme bien conçu tendant à developper l'agriculture sur des bases saines et économiques. Nous croyons que l'utilité de cette classification a été amplement démontrée; on a même pour règle aujourd'hui d'établir une classification avant d'entreprendre des travaux de développement tant soit peu importants. La classification des sols n'est pas infaillible, mais son emploi devrait supprimer les pertes immenses résultant des tentatives faites par des pionniers courageux, mais mal conseillés, pour ouvrir des fermes dans des régions qui auraient du rester en forêts, en herbages ou en pacages, et devrait réduire les déceptions qui suivent souvent l'emploi de l'irrigation. Nos programmes de colonisation, nos essais d'engrais chimiques, nos recherches générales sur les sols et nos études sur les problèmes spécifiques du sol, qui ont tous pour but de rendre l'agriculture plus lucrative, devraient être basés essentiellement sur la classification des sols, qui seule peut nous permettre d'atteindre notre but pleinement et sans frais exagérés.

REMARKS ON THE UTILIZATION OF THE SOIL SURVEY AND SOME DATA REGARDING THE SOILS OF SASKATCHEWAN[1]

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The total area of the Province of Saskatchewan is given as 251,700 square miles (*1*). About 100,000 square miles of the southern part of the province are well developed agriculturally. Along the northern fringe of this area new settlements are being established. They are for the most part situated in heavily wooded regions, where the problems of drainage, clearing the land, and somewhat low soil fertility are entirely different from the problems encountered by the pioneer settlers of the prairie to the south. Still further to the north stretches the forested area with its more numerous swamps and lakes. The northeastern section of the province is part of the pre-cambrian shield, and in this region the soils are likely to be shallow, exposures of bare rock are numerous, while lakes and rivers occupy a large share of the area. It is possible that the extreme northeast tip of the province touches the barren lands.

Practically all of the well settled area of the Province has been covered by a reconnaissance soil survey. The survey has necessarily been of an extensive nature but it is proving suitable to the type of agriculture of the province. The field work is nearing completion so that publication of the final report and map could be undertaken shortly. Tentative maps on a scale of six miles to the inch with accompanying legends have already been made by hand.

THE SOIL ZONES AND THEIR AREAS

Three distinct soil and climatic zones are to be found in the province and have been fully described by Joel (*2*); hence they do not require detailed descriptions in this paper. They are the plains, the park, and the wooded zones. Transitional between the plains and park zones is the dark brown soil belt, and there is also a transition area of a discontinuous nature between the park zone and wooded area. The park zone has been subdivided into deep and shallow park. Besides the soil differences of the different zones, there are, of course, climatic or vegetational differences or both. Between the plains and park zones both climatic and vegetational differences are easily noted but between the park and wooded zones the difference in soils seems to be chiefly due to the influence of vegetational factors. All zones have been practically completely mapped by the survey except the wooded zone, which has been only partially mapped at its southern border. It is probably the most extensive of all the zones. The areas of the zones as already mapped by the survey are as follows:

Zone	Area in sq. miles	Percentage of area surveyed
Brown Plains	30,725	32 6
Transition, dark brown prairie plains	29,240	31 1
Park: Shallow dark park	22,550	23 9
Deep dark park	2,915	3 1
Wooded grey soils (incompletely mapped)	8,750	9 3
Total	94,180	100 0

[1] Presented at the annual meeting of the Soils Groups of the C S T A at Macdonald College, P Q, June 26 and 27 1934
[2] Soils Department.

With the recognition of the major soil zones of the province and their differences in climate and natural vegetation, there is a better basis for the recognition of broad differences in agricultural adaptation. The study of such areas as the Cypress Hills where several zones are found in close proximity to one another, due to sharp variations in elevation, served in some measure to emphasize the need of considering this question.

Some of the broader differences in the agricultural adaptation of the soil zones are quite generally recognized. The better soils of the brown and dark brown plains are known to be well suited to the production of high quality wheat. Great fluctuations in yield are experienced from one season to another but on the average the yields are good for the better soil types. In the park belt wheat may be grown quite successfully but with a distinct tendency towards lower quality as measured by the protein content. Coarse grains do exceptionally well and forage crops are generally successful, especially so on the deeper park belt soils. In the wooded zone, where the typical grey bush podsolic types occur, a different problem is to be met in that these soils are generally low in fertility. Grain yields are often low although moisture conditions are usually good. A rotation including clovers, with the addition of phosphate fertilizers, has given excellent yields on these soils (3).

These few illustrations serve to make apparent some of the broader general differences in agricultural adaptation between zones. It seems likely that these variations will become more pronounced in the future as the agriculture of the province becomes older and more stab lized. The prairies, no doubt, will remain chiefly grain growing areas because of the general suitability of the soil and climate for grain production, while livestock production may become a more common type of agriculture in the park and wooded zones where forage crops can be successfully produced.

FIGURE 1. Cultivated field blowing into dunes and burying road. There are many abandoned farms in this vicinity.

THE UTILIZATION OF THE SOIL SURVEY REPORTS

A remark often heard while carrying on the work of the soil survey is, "It is a good thing but it ought to have been done forty years ago." The inference is that the value of the work is very greatly diminished because the information was not available to the first settlers It is quite true that in certain areas land has been cultivated that would have been better left undisturbed. Such mistakes have caused a great loss in both public and private capital investment and will occasion further losses. Probably an even more unfortunate phase of this situation is the wasted years and broken spirit of the settlers who found only through experience that they were encumbered with land unsuitable to the type of agriculture they had hoped to practice. The soil survey can be of great use in dealing with this problem inasmuch as it serves as the basis for any agricultural policy which may be developed to deal with these lands.

The present reconnaissance survey has already proven useful to workers in several fields of agricultural research in this province, although only a few tentative copies of the soil map have been made as yet. Entomologists, plant pathologists, agronomists and agricultural economists are among those who have found the map and related soil information a useful adjunct in their studies There are phases of such problems as soil drifting, weed control and fertilizer practice which are specifically related to soil conditions, and in the study of them a knowledge of the soil should prove of first importance. An extension of the use of soil information in dealing with agricultural problems would seem to be highly desirable since there is little doubt that the soil relationships involved in some of these problems have not been given sufficient attention heretofore. It is as an aid to the solution of such problems that the soil survey is likely to have its greatest value. While the soil survey reports (*4*) already published have been useful to many agricultural workers, their use in the various fields of Extension work has been somewhat limited since the reports covered only

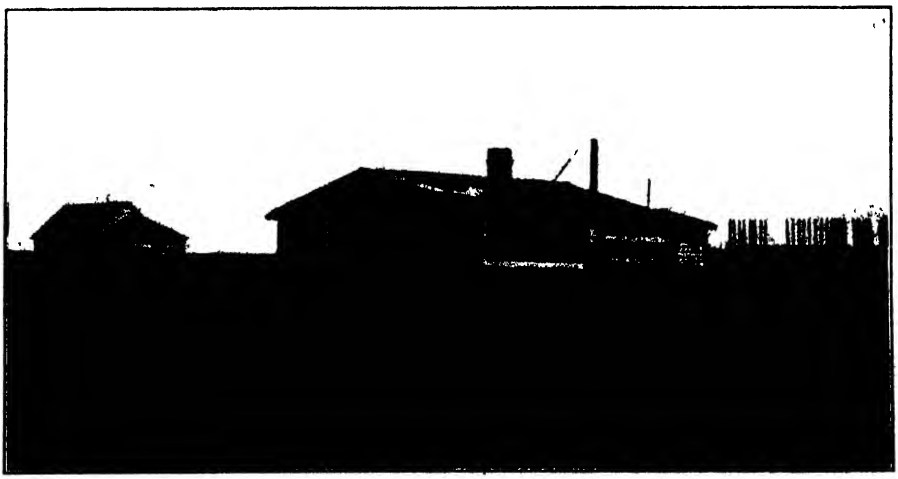

FIGURE 2. Abandoned farmstead on fine sand. A sand dune is forming in the farm yard and is threatening to cover the buildings. This is the result of cultivation of unsuitable soil.

small isolated areas of the province. However, when a map and report of the larger part of the settled area of the province are published, extension services of both public and private institutions should find them of considerable value. Certain private institutions, including banks, loan companies, and mortgage companies have been eager to obtain the published reports mentioned above, but it is probable that they were interested in them mostly because they could use the reports to assist in the valuation of land, rather than to assist in the solution of some of the problems concerned with production on the land. The maintenance of a proper harmony between the type of production practised on a farm and the type of soil upon which the farm is located should obviously be a prime consideration.

SOME DATA OBTAINED BY CLASSIFYING THE SOILS INTO GROUPS ACCORDING TO THEIR SUITABILITY FOR WHEAT PRODUCTION

Some interesting data are obtainable by classifying the soils mapped by the survey into: (1) best wheat lands, (2) very good wheat lands, (3) moderately good wheat lands, (4) fair wheat lands, (5) poor, and (6) very poor wheat lands.

The classification can be only approximate, of course, and is based more upon the combined judgments of the members of the Soils Department than actual statistical data of the productive capacity of the soils.

The results of such a classification give the following figures:

—	—	Approximate area in sq. miles
Best wheat land	7.1% of area surveyed	6,680
Very good wheat land	5.9% of area surveyed	5,560
Moderately good wheat land	16.9% of area surveyed	15,910
Fair wheat land	25.4% of area surveyed	23,920
Poor wheat land	18.5% of area surveyed	17,410
Very poor wheat land	26.2% of area surveyed	24,630

The area given for each group in the above table represents the combined area of a number of soil types. The area occupied by each type was determined directly from the soil map with the aid of a planimeter.

In brief, the tabulation of the soils of the province of Saskatchewan into the classes as given above indicates that for nearly half of the settled area of the province the land is not well suited to wheat growing. It should be pointed out that the land included in the "poor" and "very poor" classes includes the hilly, stony and sandy areas, and that only a moderate portion of these areas have been brought under cultivation. However, it is the farmer located on such lands who finds himself in a particularly distressing situation. In the case of soils classed as "very poor," it seems that ultimate abandonment and return of the cultivated land to natural grass as fast as nature will allow is the best solution. For some of the soils classed as "poor," there is a good possibility of adapting the type of agriculture to meet the soil and climatic conditions. This

adaptation is already being made by some farmers who are located on the lighter soils.

Reduced wheat acreage or practical abandonment of wheat production is a feature of the changing agricultural practices on such soils. This would seem to be wheat acreage reduction of a most desirable kind. So far, necessity has been the mother of the changing type of agriculture on the poor lands. Soil drifting, dry seasons, and weeds are some of the factors tending to force the adoption of new practices. The process of making such adjustments is only at its beginning. The rehabilitation of agriculture on lands unsuitable for wheat production is a problem involving considerable areas of this province and is one which will require the combined efforts of all those concerned with its well being.

REFERENCES

1. Atlas of Canada, 1915.
2. Joel, A. H. The zonal sequence of soil profiles in Saskatchewan, Canada. Soil Sci. *36* : 3 173-185. 1933.
3. Wyatt, F. A. The necessity of growing legumes on gray wooded soils. Sci. Agr. *14*: 6 327-335. 1934.
4. Soil Survey Reports Nos. 1-9. University of Saskatchewan

Résumé

Observations sur l'utilisation de la classification des sols et données sur les sols de la Saskatchewan. J. Mitchell et D. L. MacFarlane, Université de la Saskatchewan, Saskatoon, Saskatchewan.

La majeure partie de la région colonisée de la province de la Saskatchewan a été couverte par la classification des sols. Dans une région de ce genre, on trouve naturellement toutes sortes de sols, depuis ceux qui sont éminemment aptes à la production du blé jusqu'à ceux qui sont impropres à cette culture. Le cultivateur qui s'est établi sur des sols de cette dernière catégorie a de très grandes difficultés à surmonter. Il n'a pas encore été publié de rapports ni de cartes de cette classification mais les données obtenues ont déjà rendu de grands services aux investigateurs dans différents champs des recherches agricoles. Cette connaissance des sols pourrait être utilisée également dans l'étude d'un grand nombre de problèmes agricoles et il est vivement à désirer qu'elle le soit.

ORIGIN AND CHARACTERISTICS OF THE RED RIVER VALLEY AND REGINA PLAIN CLAY SOILS OF WESTERN CANADA[1]

By W. A. Johnston[2]

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The black clay soil of Red River Valley in Southern Manitoba, and the brown clay soil of the Regina plain in Southern Saskatchewan are two of the most extensive and important soils in the Interior Plains region of Western Canada. The two soils are similar in some respects, because of a nearly common origin of parent materials, and differ in other respects owing to climatic variations. In connection with the utilization of the soils special problems are offered to the scientific agriculturist, for over large parts of both regions only scanty supplies of usable groundwater or of surface water are obtainable, and this prohibits live-stock farming on any large scale. Both soils are affected to some extent by soil drifting, and under the present system of farming this problem is likely to become more acute in the future. A question mainly of scientific interest is the classification of these soils in any world scheme of classification. Is the black clay soil of Red River Valley a tshernosem, a meadow (groundwater) soil, or a prairie soil having affinities with the podsolic group; and how should the brown Regina clay soil be classed? Are these terms applicable to the soils of the Interior Plains region of Canada? In this paper the problems associated with the utilization of the soils are not discussed or are only briefly referred to, as their solution is the work of the scientific agriculturist; the character of the soils both with reference to the parent materials and to pedogemic processes is described and their classification briefly discussed. The paper is offered as a contribution to our knowledge of the soils of the Plains region and is presented mainly from the geological standpoint; a thorough knowledge of the character of the soils is necessary in attempting to solve problems that are bound to arise in the future because of soil drifting and other conditions such as the scarcity in some areas of ground-water supplies.

THE RED RIVER VALLEY CLAY SOIL

Red River Valley is a nearly level plain drained by Red River flowing north into Lake Winnipeg, and by Assiniboine River coming from the west and joining the Red at Winnipeg. These streams and their few tributaries occupy comparatively narrow and steep-sided valleys, 20 to 50 feet deep. Large parts of the plain have no natural drainage and were formerly marshy in wet seasons, but have been drained for the most part by ditching. The plain is an ancient lake bed formed several thousand years ago during the melting away of the last ice-sheet. It has been modified to some extent since the lake was drained by stream erosion and by deposition from overflow of the streams. Assiniboine River overflows its banks in places nearly every year, but only twice since the earliest days of settlement has Red River overtopped its banks, once in 1826 and again in 1852. When the first settlers entered the region over 100 years ago,

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[1] Published with the permission of the Director of the Bureau of Economic Geology, Department of Mines, Ottawa, Canada

[2] Chief, Borings Division.

the great part of the valley was found to be prairie and this greatly favoured pioneering. Forests grew mainly along the streams. The soil thus is a prairie soil. It is doubtful whether Red River Valley has been forested to a greater extent than at present at any time since the former lake was drained, for the clay shows no evidence of root penetration of former trees. As has frequently been pointed out, prairie vegetation has been favoured owing to prevention of natural regeneration through prairie fires and the effects of grazing animals. Prairie fires must have periodically swept the valley from end to end owing to the few natural fire guards and to the drying of the marshes in times of drought; and the grazing of the countless herds of bison that once roamed the Plains region must have had an important effect in preventing the spread of forests. That the rainfall or ratio of evaporation to rainfall is sufficient for the growth of forests is shown by the results of tree planting and the occurrence of extensive forests in adjacent areas that have the same rainfall or somewhat less.

The clayey part of the former lake basin on which the Red River Valley clay soil is developed, occupies a wide belt along Red and Assiniboine Rivers. Near the International Boundary, the belt extends 10 miles east of Red River and 20 miles to the west. It widens to the north, and on the latitude of Winnipeg, extends 20 miles to the east and 60 miles to the west along Assiniboine River. The area, approximately is 4,500 square miles. Surface and soil conditions vary somewhat in different parts, but over the greater part are fairly uniform. Small areas along Assiniboine River are subject to overflow in times of freshet, and there are in places undrained areas that are partly flooded in wet seasons and become dry in times of drought. In these areas there is no accumulation of peat at the surface; but in the northeast along the valley of Brokenhead River where flooding is more pronounced, peat has accumulated at the surface and soil conditions are markedly different.

Climatic conditions are those characteristic of an interior continental region; the winters are cold and the summers warm. At Winnipeg the mean temperature for January from 1885 to 1930 ranged from −14.5° to 7.8° F., and for July from 61.4° to 72.3°. Precipitation ranged from 13.76 inches (1917) to 27.19 inches (1898) and averaged nearly 20 inches. Precipitation in the southern part of the area near the International Boundary is slightly less than at Winnipeg. About 60% of the rainfall comes in April to July inclusive. The length of the growing season free from killing frosts ranges from 100 to about 140 days. Taking into consideration the relationship of evaporation to precipitation the climate may be classed as sub-humid, that is, intermediate between humid and semi-arid.

Ground-water conditions in the area are markedly influenced by the climate and by the character of the surface deposits overlying the bedrock. The surface deposits average over 50 feet in thickness and consist of stratified clays overlying boulder clay. Nearly impervious clay lies at a depth of 6 to 10 feet, the upper clay being more porous and containing sand and silt in its lower part. The lower clay acts as a seal for artesian water in the vicinity of Winnipeg and at other places. Owing to the high absorption properties of the soil and of the upper clay, a considerable part

of the rainfall passes downward and is held by the impervious clay below to form a source of ground-water for growing plants. The upper surface of the zone of saturation in the clay lies at a depth of 10 or 15 feet to above 40 feet. Wells sunk in the clay yield only small supplies, for seepage of water from the clay is extremely slow. The water has a marked temporary and permanent hardness and a fairly high proportion of soluble salts in solution. What proportion of the rainfall is absorbed by the soil is not definitely known but it must be fairly high for only in the poorly drained areas does water lie after heavy rains. There is a nice balance between rainfall, evaporation and absorption; a rainfall equal to that of the more humid region to the east would result in flooding large areas.

The soil formed in Red River Valley varies somewhat depending partly on whether it is developed on the alluvial clay along the stream valleys or on the lake clay, the former as a rule being a much deeper soil. A soil profile on the alluvial clay at Winnipeg is as follows:

1. Black humus stained clay showing columnar structure in places but for the most part breaking down into irregular lumps and eventually into a fine-grained granular mass. Slightly calcareous particularly in the lower part. Depth 12 to 14 inches.

2. Greyish-black clay showing poorly defined columnar structure, and irregular blocks separated by vertical shrinkage cracks. The black clay extends downward in long tongues into yellowish grey clay. Soft irregular masses of calcium carbonate up to one or two inches in diameter occur both in the black clay and in the grey clay which is somewhat sandy and silty. Maximum depth of the humus stained clay about 30 inches.

3. Yellowish-grey, granular clay that is highly calcareous. There is a marked accumulation of calcium carbonate in the lower six inches which is sharply set off from the underlying material at a depth of 4 to 4½ feet from the surface. The layer is a soft marly clay.

4. Light grey, stratified, calcareous clay.

In the lake clay areas, horizon No. 1 extends to about the same depth and is similar in character; horizon No. 2 is not so deep and contains comparatively little humus stained clay. There is a gradual transition downward into the parent material and a gradual increase in the concentration of calcium carbonate to a depth of about 3 feet but no very marked lime layer. The soil has been leached to some extent by downward passing surface waters but not completely, for even the surface soil in places is slightly calcareous.

The most striking features of the Red River Valley clay soil are its deep black color and the great depth—3 feet or even more in places—to which the dark color extends. The dark color is due to the presence of colloidal humus that is uniformly distributed through the clayey mineral part of the soil and whose formation has been greatly favoured by climatic and other conditions. Roots of prairie grasses and possibly in places vegetation buried beneath the silt deposited by flood waters formed an abundant source of organic matter that was readily altered to humus owing to the character and structure of the mineral soil. The calcareous character of the clay tends to produce a granular structure, and owing to its colloidal character shrinkage cracks readily develop in times of drought,

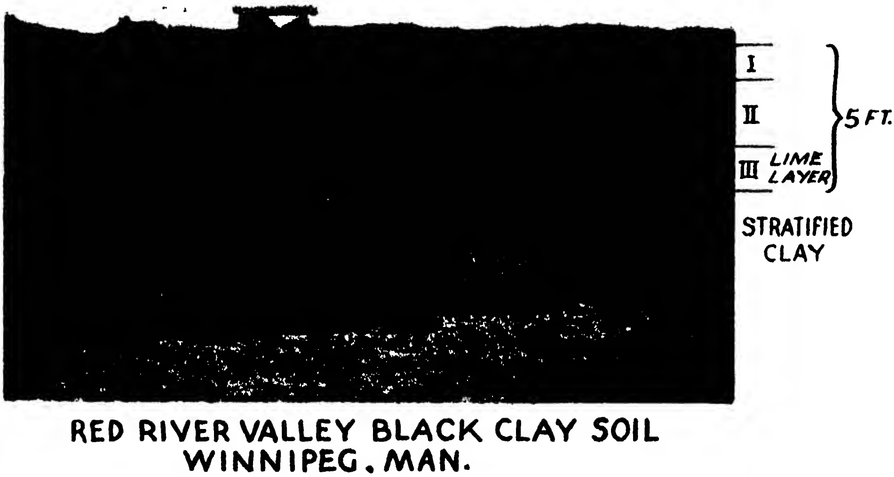

FIGURE 1. Red River Valley black clay soil, Winnipeg, Man.

thus causing aeration of the soil and alteration of the organic matter to humus, though the exact process by which alteration takes place is not known and may be highly complicated. In places the burrowings of animals may account for humus stained soil at a depth of as much as three feet, but at many places along Red River the black soil extends nearly to this depth in a fairly uniform layer and can hardly be accounted for in this way; more probably it is an alluvial soil. In the alluvial soil, however, the soil profile, as a rule, is a mature one owing to the infrequent periods of overflow of the stream.

It is doubtful whether the calcium carbonate layer should be considered as part of the soil profile owing to the depth at which it occurs, though it has been formed in part at least by downward leaching from the soil horizons.

How should the Red River Valley clay soil be classed in any world scheme of classification? It is not, at least for the most part, a meadow or ground-water soil, for it is best developed along Red River at places where there is good drainage both at the surface and underground; and except in the northeast there is no accumulation of peat at the surface even in the poorly drained areas. It has few if any affinities with the podsols of the more humid region to the east; it is a prairie soil that is only slightly leached and there is no translocation downward of the clayey fraction of the soil. Even the forested parts of the soi do not show these characters to any marked degree, and it seems doubtful whether the term podsol should be applied to any of the soils of the sub-humid Interior Plains region.

In some respects the soil markedly resembles the tshernosems or black earths as described by G. W. Robinson in his recent text-book on *Soils, Their Origin, Constitution and Classification*, and there is little doubt that it closest approaches this group of soils. In color and depth of the humus soil, in its structure and only partly leached character it resembles

the black earth soils. It differs in the absence of hard calcareous concretions and in the greater depth and, in places, poorly developed character of the calcium carbonate layer. The differences may be due partly to somewhat more humid conditions than are commonly found in black earth regions of north temperate latitudes and to differences in the parent materials.

THE REGINA PLAIN BROWN CLAY SOIL

A large area in Southern Saskatchewan that was formerly a lake bed, as was Red River Valley, is underlain by thick deposits of stratified clay on which a remarkably uniform brown clay soil is developed. The lake clays extend in a broad belt from Moose Jaw and Regina southeast nearly to Weyburn, and continue to the northwest along the South Saskatchewan valley. They occupy an area of several thousand square miles and form one of the most important of the agricultural belts in the province. In contrast to the nearly level surface of Red River Valley, much of the Regina clay plain is gently rolling but is generally smooth and free from stones and boulders. Sections show that the clay is extremely fine-grained and has been much disturbed by fracturing and distortion of the bedding which is only faintly visible because of the nearly uniform grain of the material. Possibly uneven settling of the highly collodial material after drainage of the lake resulted in unevenness of the surface.

Temperature conditions in the area, as shown by the Meteorological Service of Canada, are practically similar to those at Winnipeg, though the region has a general altitude of 1,800 to 1,900 feet above the sea, about 1,000 feet higher than Red River Valley. Precipitation at Regina has ranged from 8.04 inches (1886) and 8 54 inches (1917) to 22 67 inches (1890) and 22.53 inches (1927), with an average of about 16 inches. Conditions thus are markedly drier than in Red River Valley. Probably also the effects of drying winds are more pronounced because of the general absence of natural wind breaks, for nearly all the region is open prairie and has little relief.

Ground-water conditions in the Regina plain are markedly affected by climatic conditions and by the nearly impervious character of the lake clay. In places, for example near Regina, artesian water is found below the clay, but over large areas only scanty supplies of seepage water are obtained from the clay, and borings at depth find no supplies of usable water. In places sands and gravels occur at or near the surface, and in these water is commonly found but the sands are not very widespread. In the clay areas well borings generally show a shallow zone of saturation of the clay at a depth of 15 to 25 feet. Below this zone the clay may be nearly dry. Owing to the fine-grained character of the clay and its granular and jointed structure in the upper few feet, a large part of the rainfall is absorbed. In times of drought shrinkage cracks extend downward for several feet from the surface, and these aid in causing downward percolation of the surface water. In wet seasons and especially in spring, water may remain on the surface for some time in low-lying places and, as the great part of the plain has no natural drainage, there is comparatively little run off. The part of the rainfall that is absorbed extends downward only to shallow depths and forms the main source of water for growing plants.

The soil developed on the lake clay has been described by the Soil Survey of the Province of Saskatchewan under the name Regina Clay. The soil profile at Regina is as follows:

1. Greyish brown to dark brown clay showing columnar and irregular clod structure, eventually breaking down into a fine granular mass. Calcareous. Depth 12 to 15 inches.

2. Brown clay showing columnar and irregular contorted structure. Calcareous. Depth about 20 inches

3. Light brown and grey clay showing concretionary calcium carbonate in small vertical and irregular masses. The upper limit of the calcium carbonate layer is a fairly definite line at a depth of 2½ to 3 feet from the surface; the lower limit is irregular.

4. Poorly stratified light brown and buff clay much faulted and disturbed, and containing hard concretions of calcium carbonate and small crystals of gypsum. The effects of weathering in destroying the original structure of the clay extend to depths of 5 to 7 feet from the surface.

Like the Red River Valley clay soil, the Regina clay soil granulates readily under cultivation because of its high organic matter content in the form of collodial humus and its calcareous character. It is a heavier soil and more calcareous in the A horizon Its most marked difference is the brown color rather than black. This seems to be due to the drier climatic conditions, for other conditions seem to be nearly similar, and over the drier parts of southern Saskatchewan all the soils tend to be brown whereas those in southern Manitoba have a much darker color. The organic matter content of the Regina clay soil, however, may be nearly as great as that of the Red River clay though the soil is not so deep.

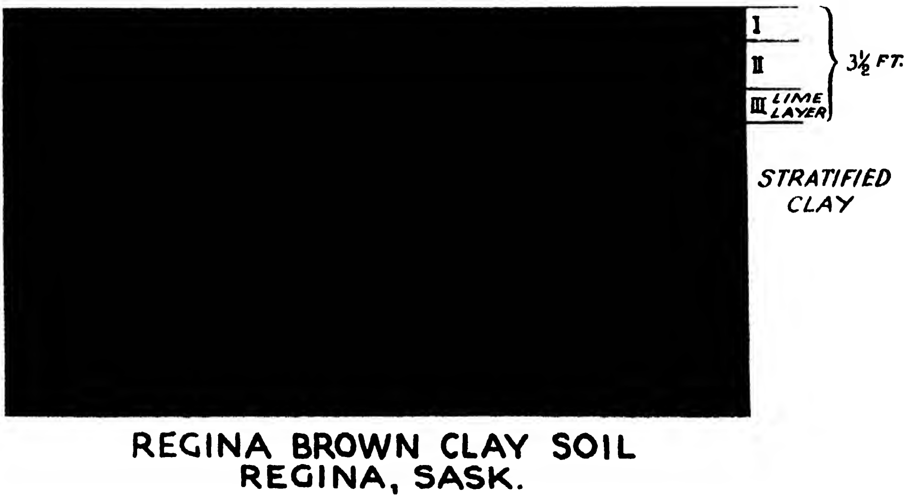

FIGURE 2. Regina brown clay soil, Regina, Sask

The lime layer in the Regina clay is not well marked and lies at a considerable depth in spite of the dry climatic conditions. Its poorly marked character and the depth at which the small accumulations of calcium carbonate occur may be due partly to the colloidal character of the clay which causes it to crack badly in times of drought. Shrinkage cracks allow the surface waters to percolate downward to considerable depths, and these waters on evaporation deposit from the concentrated soil solutions calcium carbonate in the form of concretions and crystals of gypsum. In Southwestern Saskatchewan south of the Cypress Hills, where still drier conditions prevail, the lime layer is well marked and occurs at a depth of only about one foot from the surface. This illustrates the well known fact that the lime layer tends to approach the surface the more arid the climate; but variations may occur owing to the character of the soil.

In some respects the Regina clay soil resembles the chestnut-colored earths characteristic of semi-arid regions, but differs in the finely granular texture of the A horizon and the poorly developed character of the lime layer. These differences may be due to the collodial character of the clay, and to climatic conditions which may be regarded as on the borderline between sub-humid and semi-arid. It may be that because of the youthful age of the soils, geologically, typical tshernosems and chestnut-colored soils have not been developed in the Plains region of Western Canada.

SOIL DRIFTING

The causes of soil drifting are well known and have been well described in the University of Saskatchewan Soil Survey reports. High winds in times of drought coupled with dry farming methods which demand excessive cultivation of the soil and the granular character of the soil are the main causes. Various remedies have been suggested.

Both the Red River and Regina clay soils in spite of their heavy clay character are affected by soil drifting though not to the same extent as are the sandy soils. The very factor which renders the clay soils easily cultivated and highly productive, namely their finely-granular texture due to the high organic matter content in the form of humus, also renders them easily affected by soil drifting. Small rounded clay grains which at first glance appear to be sand grains drift before the wind, fill ditches and accumulate along fences and other barriers to form clay banks which when wetted by rains again become sticky clay. The finer material is taken into the air to form dust clouds that are carried far to the east by the prevailing westerly winds. In recent years the dust storms have become more frequent, and their extent far to the east in the spring of the present year caused widespread comment. Their effect on the Red River and Regina clay soils, however, is not so serious as might be supposed because soil drifting occurs only in times of drought, it affects only limited areas and the great depth of the humus soil prevents exposure of the subsoil. Nevertheless under the present system of farming, which because of climatic and other conditions seems a necessary one at least for large areas, soil drifting is likely to become more pronounced in the future and demands a remedy, though the intervention of a series of wet years may temporarily solve the problem. In connection with utilization of these soils most

investigators probably will agree that maintenance of their natural fertility is not a major problem. The soils are entirely different from those found in the more humid region of eastern Canada. Because of the sub-humid climate and mode of origin of the soils they have abundant stores of humus and of calcium and other salts in the soil solutions. The main problems are the proper utilization of the soils under the climatic and ground-water conditions that prevail, and the prevention of soil drifting.

Résumé

Origine et caractères des sols argileux de la vallée de la Rivière Rouge et de la plaine de Regina. W. A. Johnston, Commission géologique, Ministère des Mines, Ottawa.

Sous certains rapports, les sols argileux de la vallée de la Rivière Rouge ressemblent au groupe tshernosem de sols ou de terres noires, et les sols argileux de la plaine de Regina présentent quelques-uns des traits caractéristiques des terres couleur marron, mais pas tous. Ces deux genres de sols sont formés sur diluvium glaciaire; ils sont donc jeunes au point de vue géologique. Leur jeunesse, les différences que présentent les conditions climatériques et autres, peuvent expliquer pourquoi ils diffèrent des groupes bien reconnus de sols, comme les tshernosems et les terres de couleur marron.

SOIL TYPES OCCURRING IN THE RED RIVER VALLEY PLAIN[1]

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INTRODUCTION

The soils in the Red River Valley in Manitoba afford an excellent illustration of the great differences in soil type that may occur in associated soil profiles developed on the same parent material, and also of the varietal differences which may result within soil types (or groups) because of differences in parent material. The purpose of this paper is to present a brief description of this area; to point out the soil types (or groups) which occur,[3] and to indicate the determining factors responsible for the soil type variation. Incidentally the method of cataloguing or classifying the widely different soils, in the field-system of classification used is illustrated (*1*)

GENERAL DESCRIPTION OF THE RED RIVER VALLEY

The physiographic region locally defined as the "Red River Valley" in Manitoba is a wide expanse of grassland plain, occupying the basin of the glacial Lake Agassiz, through which the Red River flows from the International boundary to Lake Winnipeg. In the virgin condition this area constituted the northeastern portion of the grassland-plains immediately adjacent to the forest-region. In its northern and eastern portion there is now evidence of recent woodland invasion. The native vegetation at the present time may be divided into three types.

I. The tall-grassland-prairie formation.

II. The meadow-grassland formation.

III. The woodland vegetation, which may be sub-divided into

(*a*) the oak-elm-box elder woods of the river terraces

(*b*) the recent willow-poplar-oak woodland invasion of the meadows and prairies.

The distribution of these vegetative types is indicated in Figure 1.

The outstanding topographical feature of the so-called "Red River Valley" is its broad flat expanse of plain characterized by the general absence of macro- and meso-relief In the southwestern portion which

[1] Presented at the annual meeting of the Soils Group of the C S I A at Macdonald College, P Q June 26 and 27 1934

[2] Soils Division, Department of Agronomy

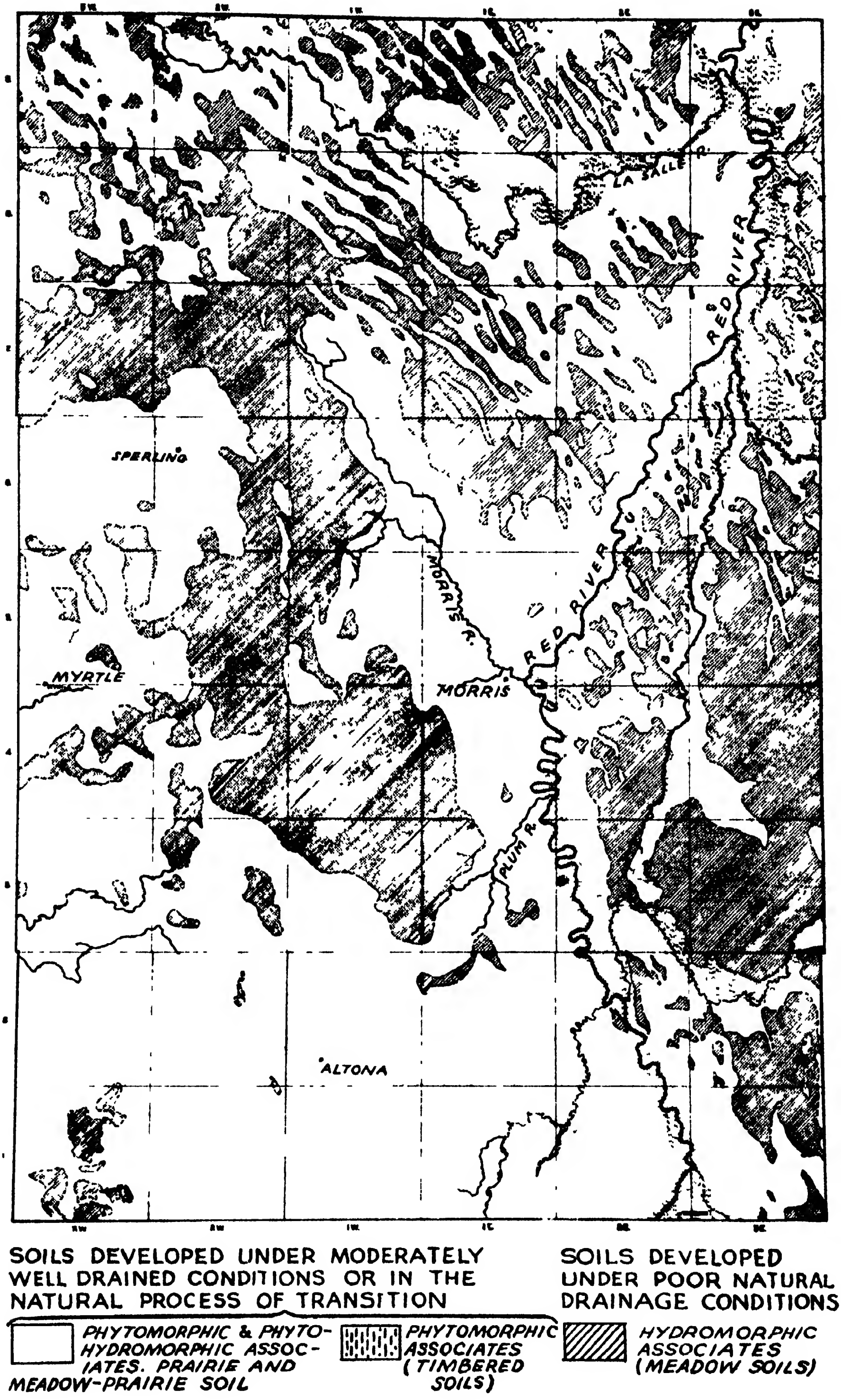
[3] The area which was covered by reconnaissance survey consisted of approximately 1 250 000 acres or 54 townships located in townships 1 (one) to 9 (nine) from ranges 3 (three) west to 3 (three) east of the principal meridian The work was carried out by the Manitoba Soil Survey under the direction of the author as a joint project conducted co-operatively by the Dominion Experimental Farms the Provincial Department of Agriculture, and the University of Manitoba

Figure 1. Relationship of Soils and Native Vegetation (See opposite page)

Soils developed under moderately well drained condition, or in the process of transition to well drained conditions.

1. Phytomorphic and phytohydromorphic associates under prairie and meadow-prairie = unhatched.
2. Phytomorphic wooded associates under timber = broken vertical hatching.

Soils developed under poor natural drainage conditions; meadow-grassland vegetation = diagonal hatching.



SPERLING
MYRTLE
MORRIS
MORRIS R.
RED RIVER
LA SALLE R.
PLUM R.
ALTONA
SOILS DEVELOPED UNDER MODERATELY WELL DRAINED CONDITIONS OR IN THE NATURAL PROCESS OF TRANSITION
SOILS DEVELOPED UNDER POOR NATURAL DRAINAGE CONDITIONS
PHYTOMORPHIC & PHYTO-HYDROMORPHIC ASSOCIATES. PRAIRIE AND MEADOW-PRAIRIE SOIL
PHYTOMORPHIC ASSOCIATES (TIMBERED SOILS)
HYDROMORPHIC ASSOCIATES (MEADOW SOILS)

lies above the 820 foot contour, the terrain has developed a young relief system with a fall of from eight to two feet per mile. The soils of the Altona Association occur in this portion; they are comparatively well drained. Below the 820 foot contour and throughout the central plain, however, the only relief, other than micro-relief, is *(a)* the very few canal-like channels cut by the rivers and streams into the easily eroded lacustrine sediments, and *(b)* the low wave-formed clay ridges found in the vicinity of the 780 foot contour. These low clay ridges run in a northwesterly and southeasterly direction; they correspond to the flat shore lines of Lake Agassiz during the Niverville stages. In the central clay basin (on which the soil of the Red River Association occurs) the altitudes above the river banks range only from 820 down to 765 feet; the fall in this portion varies from two to less than one-half foot per mile. Thus extensive areas of imperfectly drained soils are found, which, in the virgin condition, were covered with swales and broad shallow marshes, so that, in the Red River Soil Association typical well drained soils only occur adjacent to the stream channels, or on the above mentioned ridges (Figure 1).

Climate

The climate of the area as a whole is shown by the meteorological data recorded at Oakbank, Winnipeg and Morris, located on the central clay plain, and at Morden and Almassippi, located on the lighter textured area immediately to the west (*2*). The precipitation and temperature records available for varying periods of years are summarized in Table 1 and Table 2 respectively.

If the "precipitation effectivity index" (P/E)[3] and the "temperature efficiency index" (T/E) at each of these points are calculated according to the formula suggested by Thornwaite (*3*) the following values are obtained.

	P/E	T/E
Oakbank	54.0	35.67
Winnipeg	52.0	38.31
Morris	44.7	41.05
Almassippi	46.0	39.22

These values indicate that the climate is not uniform throughout. On the basis of Thornwaite's theory, black earth (chernozem) soils would be regional in the central and southern portion, but in the north eastern part of the "valley" a somewhat more humid climate is indicated.[4]

SURFACE GEOLOGY AND PARENT MATERIAL

The general surface geology of the area has been described by Upham (*4*) as lacustrine sediments. In the soil survey of the area the surface geological deposits were further subdivided into eight different soil parent materials, each having its own "association" of soils. The type of deposit,

[3] P/E index = summation of each monthly precipitation effectiveness $\sum^{12} 115\left(\frac{P}{T-10}\right)_n^{\frac{10}{9}}$

where P = monthly precipitation in inches, T = mean monthly temperature in F°, $_n$ = 1, and T values below 28.4° are taken as 28.4°.

T/E index = $\sum^{12}\left(\frac{T-32}{4}\right)_n$ where T = mean monthly temperature, $_n$ = 1, and T values below 32° are taken as 32°.

[4] According to Thornwaite's theory P/E values of 32 to 47 indicate the occurrence of chernozem soils and P/E values of 48 to 67 indicate the occurrence of prairie-earths.

TABLE 1.—MEAN MONTHLY, SEASONLY AND YEARLY PRECIPITATION IN INCHES AT LOCAL METEOROLOGICAL POINTS

	Nov.	Dec.	Jan.	Feb.	Mar	April	May	June	July	Aug	Sept	Oct	Winter Ppt.	Summer Ppt.	Total yearly precipitation
Oakbank 1885–1928 44 years	1·10	0·92	0·99	0·84	1·19	1·65	2·04	3·16	2·84	2·04	2·32	1·46	5·03	15·55	20·58
Winnipeg 1874–1930 57 years	1·11	0·94	0·83	0·85	1·13	1·37	2·23	3·11	3·08	2·39	2·20	1·51	4·84	15·86	20·70
Morris 1916–1928 13 years	1·15	0·71	0·75	0·65	0·95	1·15	1·77	2·84	2·39	2·37	2·39	1·30	4·21	14·22	18·43
Almasippi 1907–1928 22 years	0·88	0·79	0·86	0·71	1·03	1·43	1·95	2·81	2·87	1·91	2·32	1·16	4·32	14·45	18·77
Morden 1885–1928 44 years	1·06	0·89	0·77	0·72	1·10	1·36	1·91	3·18	2·59	1·85	1·82	1·19	4·56	13·92	18·48

TABLE 2.—MEAN MONTHLY, SEASONAL AND YEARLY TEMPERATURE IN DEGREES FAHRENHEIT AT LOCAL METEOROLOGICAL POINTS

	Nov.	Dec.	Jan.	Feb.	Mar	April	May	June	July	Aug.	Sept.	Oct	Winter mean	Summer mean	Yearly mean
Oakbank 1905–1928 24 years	23·95	6·39	−1·86	1·86	17·82	36·77	50·81	60·59	64·77	61·42	53·55	38·77	9·69	52·39	34·73
Winnipeg 1875–1930 56 years	21·88	5·38	−3·19	1·25	15·81	38·01	51·94	62·13	66·53	63·72	53·93	41·01	8·22	53·89	34·92
Morris 1916–1928 13 years	24·69	6·00	0·00	4·33	19·99	37·69	52·76	61·29	66·83	64·30	55·38	40·00	11·04	54·07	36·27
Almasippi 1916–1928 13 years	25·47	7·23	1·84	6·53	21·23	37·53	52·53	66·61	66·83	63·99	54·99	41·23	12·49	54·14	36·91
Morden 1905–1928 24 years	26·03	9·13	1·91	5·86	20·95	37·94	51·38	62·20	66·82	64·47	55·79	42·30	12·82	54·49	37·25

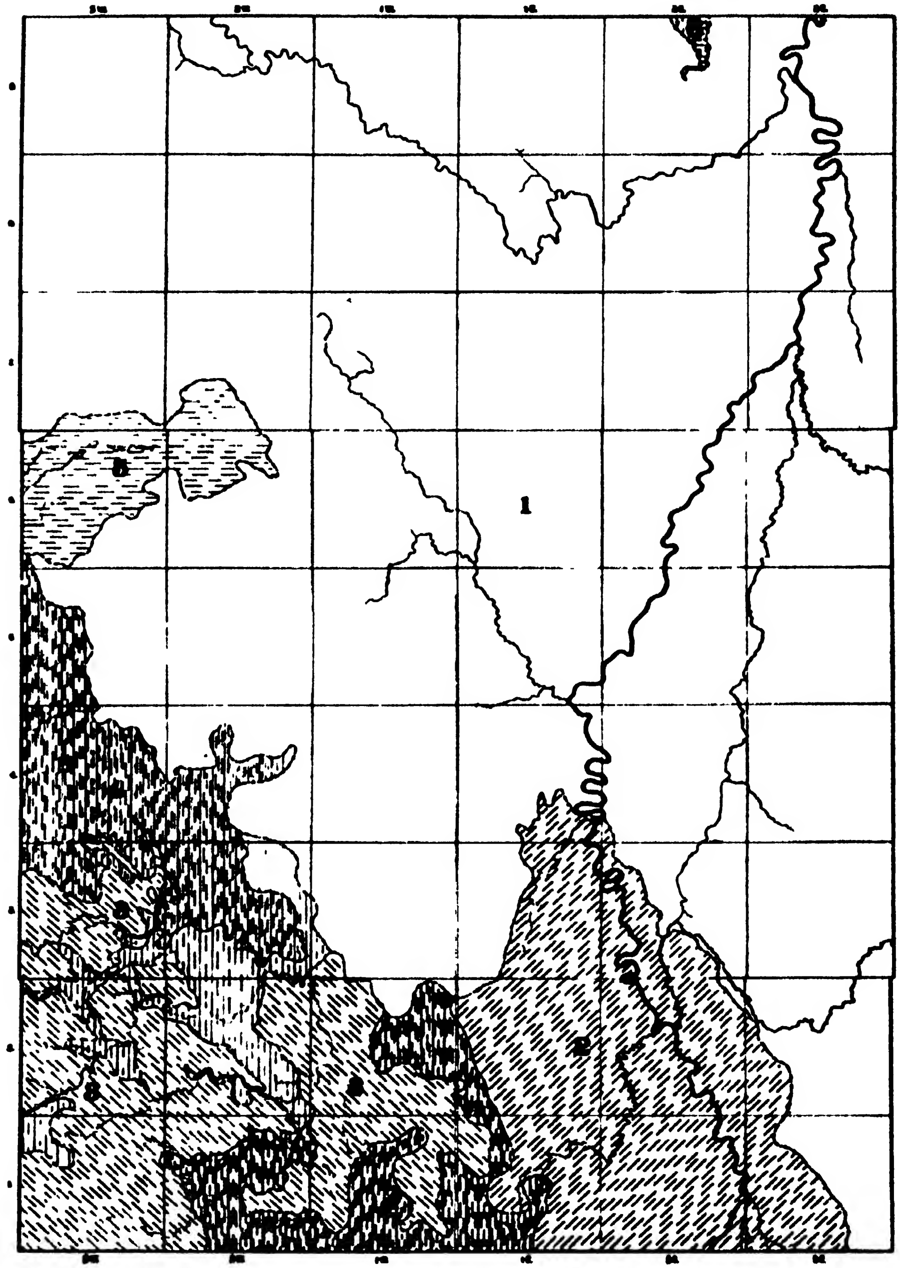


FIGURE 2. Distribution of Soil Associations

1. Red River Association developed on Lacustrine fine clay.
2. Emerson Association developed on Delta silt.
3. Altona Association developed on Sandy sediments.
4. Gretna Association developed on Cretaceous clay overwash.
5. Sperling Association developed on Stream outwash and levee.
6. Fort Garry Association developed on Mixed Lacustrine clay and dolomitic outwash.

or parent material, and the name given to the soil association occurring on each is given in Table 3. The distribution of six of these "soil associations" is shown in Figure 2. The other two soil associations are too small in area to be shown on a map of this scale.

DIFFERENCE IN SOIL DUE TO PARENT MATERIAL

The three major soil associations, namely the Red River, the Emerson, and the Altona comprise 82 69% of the area studied, hence the well drained soils (i.e. phytomorphic associates) of each of these three "associations" may be taken as constituting the typical regional soils developed respectively on heavy, on medium to heavy, and on light textured parent materials. These three phytomorphic "prairie-associates" are the normal soils developed in this area, under grassland, due to the influence of the "regional climatic" soil-forming processes; nevertheless, marked variations occur in their respective soil profiles. These variations are chiefly in the color and depth of horizons, in the texture and the structural aggregates, and in the organic matter and carbonate content. These variations are the result of the differential expression of the regional soil-forming processes on materials of different textural and minerological composition. Varietal differences due to parent material are seen also when either the meadow or other soil types (or groups) are compared. The major differences in the profiles of the Red River, Emerson, and Altona phytomorphic "prairie associates" are shown in Figure 3.

DIFFERENCES IN SOILS DUE TO ENVIRONMENT

Eight different morphological soil types (or groups) and a number of types are found in this area. However, all of the various morphological or genetic soil types do not occur in each "soil association" For example

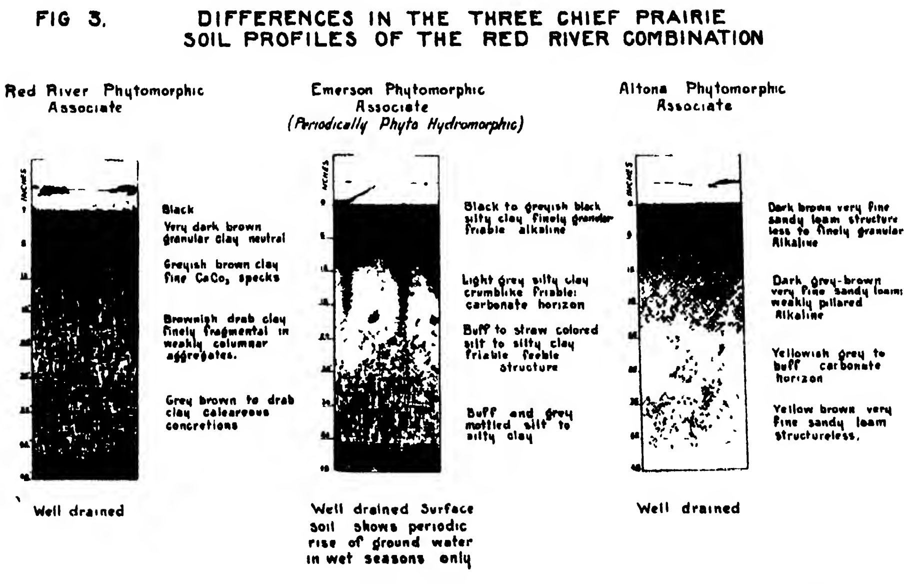


FIGURE 3. Differences in the three chief Prairie soil profiles of the Red River combination.

only two soil-types occur in the Altona and four in the Emerson "soil associations," but all of the eight types are found as "Associates" on the heavy clays of the "Red River Association." This latter "soil association" covers approximately two-thirds of the area studied. As this association contains all the morphological soil types of the area, it affords an excellent example of the variation in soils developed on the same parent material resulting from differences in native vegetation, drainage, position, etc. The number of soil types occurring in each of the "soil associations" and the method of cataloguing or classifying them in the field is presented in Table 3.

Space does not permit of a detailed description of the various soil profiles found; the key, however, to the soils of the "Red River Association" which have been developed on the fine lacustrine clays gives an indication of the soil variation and of the numerous soil types that occur on this parent material. The morphological differences of the five most important types are illustrated by the sketches in Figure 4.

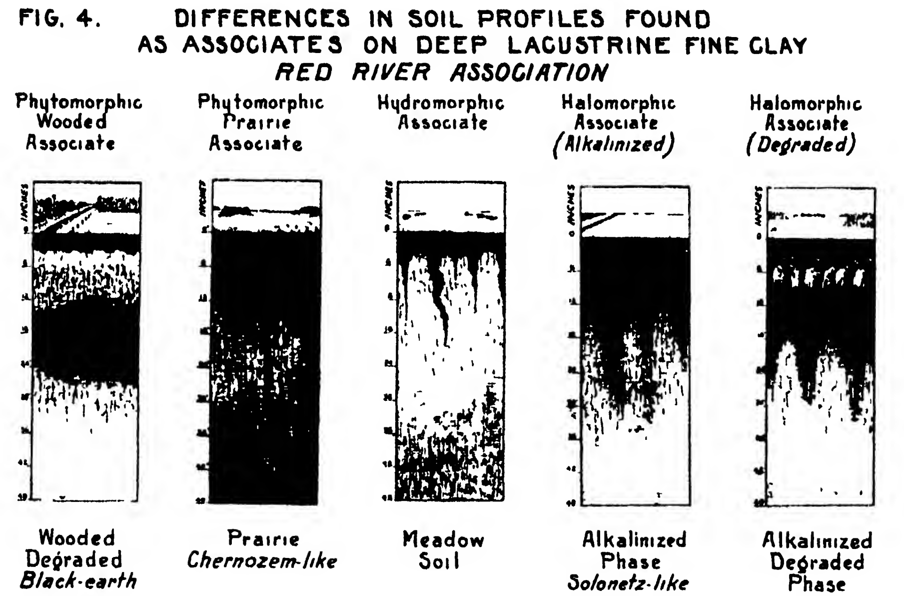


FIGURE 4. Differences in soil profiles found as associates on deep lacustrine fine clay Red River Association.

KEY TO SOILS IN RED RIVER ASSOCIATION

B_1 Soils in association on deep lacustrine fine clays .....RED RIVER ASSOCIATION—

C_1 Soils developed under well drained or normal moisture conditions .. . .PHYTOMORPHIC ASSOCIATES

D_1 Well drained prairie.

Soils with very dark brown to black friable A horizon with granular structure, neutral reaction, tongued with icicle-like instrusions into the underlying greyish brown to drab clay. Effervesces with acid immediately below the dark A horizon.. ... .Red River Clay*

*Soil series names for local use are included in the above key.

TABLE 3.—A_1 SOILS OF RED RIVER COMBINATION
LAKE AGASSIZ BASIN

Soils developed on—	Name of association	Associates: C_1 Phytomorphic D_1	C_1 Phytomorphic D_{1-3}	C_2 P. H. D_{1-3}	C_3 Hydromorphic D_1	C_3 Hydromorphic D_2	C_4 Halomorphic D_1	C_4 Halomorphic D_2	C_4 Halomorphic D_3	Per cent of total area
		Prairie associate	Wooded associate	Phyto-hydromorphic	Non-salinized phase	Salinized phase	Salinized phase	Alkalinized phase	Degraded phase	
B_1 Deep lacustrine clay	Red River	+	+	+	+	+	+	+	+	66·19
B_2 Delta. silt and lacustrine sediments	Emerson	+	+	+		+				8·22
B_3 Sandy, shallow lacustrine sediments	Altona	+				+				8·27
B_4 Cretaceous clay overwash	Gretna	+				+	+	+		7·73
B_5 Stream outwash and levee	Sperling	+								1·18
B_6 Mixed lacustrine clay and dolomitic outwash	Fort Garry			Complex			Complex	Complex		0·15
B_7 Gravel beach deposits	Agassiz	+								
B_8 River terrace silty deposits	Riverdale	+		+						1·31
Alluvium, and transitional types										6·94+
Per cent of total area		36 94		12·23	29·16		14 72			
Soil types (Groups)		Blackearth (Chernozem-like)	Degraded blackearth	Meadow-Prairie	Meadow	"Solonchak"	Salinized "Solonetz"	"Solonetz-like"	"Solod"	

+ Soil types observed

Oromorphic associates absent.

D_2 Wooded associate (or degraded prairie)

Soil degraded by woodland invasion of prairie. Acid in upper portion of profile, with distinct grey A_2 horizon and tough cloddy darker colored B horizon — St. Norbert Clay

D_3 Prairie-woodland transition.

Transition soil between D_1 and D_2 similar to D_2 but without grey A_2 horizon .. — Red River Clay (scrub phase)

C_2 Meadow-prairie soils in transition from meadow to prairie . PHYTO-HYDROMORPHIC PHASE

D_1 Meadow-prairie phase or immature phase of Red River Clay.

Better drained phase of transition from meadow-prairie. Soils with black A horizon. Tongued into olive drab clay and with lime carbonate concretions . . — McTavish Clay

D_2 Meadow-prairie transition between Red River association and Sperling association.

Similar to D_1 but not so heavy in texture — McTavish Silty Clay (deep phase)

D_3 Poorer drained phase of D_1 but somewhat better drained than Osborne clay — McTavish Clay (Low phase)

C_3 Meadow soils developed under locally excessive moisture ..HYDROMORPHIC ASSOCIATES

D_1 Non-salinized meadow associate. Soils with shallow black A horizon over a grey glei-like clay horizon with more or less profuse iron specks or streaks and concretions. May have thin deposit of muck or peaty material on surface if virgin — Osborne Clay

D_2 Salinized meadow associate.

As D_1 but with gypsum crystals and salting within the soil profile — Osborne Clay (Salinized phase)

C_4 Alkalinized Associates HALOMORPHIC ASSOCIATES

D_1 Salinized or shallow phase.

Soil in transition between salinized Osborne clay and Morris clay, with tough black A horizon and feebly developed alkalinized structure over grey clay with profuse carbonate concretions, and gypsum crystals, and more or less salting — Morris Clay (Salinized phase)

D_2 Alkalinized phase

Soils with deep black waxy surface Tough waxy B horizon with prismatic or columnar cloddy structure over grey clay — Morris Clay

D_3 Degraded phase.

Soils in which the A horizon is becoming gray and more or less ash-like over a B_1 horizon with large columnar clods below which is a tough black tar-like B_2 horizon underlain by a gray clay with carbonate concretions ....Morris Clay (Degraded phase)

FACTORS RESPONSIBLE FOR SOIL VARIATION

It is evident from the study of the soils of the Red River Valley that the differences in the soil profiles reflect the differential influence of a number of determining factors. The factors here involved may be enumerated as: *(a)* "climate," *(b)* "parent material," *(c)* "native vegetation," *(d)* topographical "position" or "relief," *(e)* the "presence or absence of "ground water" (salinized or non-salinized) and *(f)* "age."

(a) The effect of the regional "climate" is evidenced in the development of black-earth soils in the normal or well drained position under prairie-grassland.

(b) The effect of different "parent material" is apparent in the varietal differences which appear when the soils of any specific type (or group) are compared

(c) The effect of "native vegetation" is shown in the soil profiles of the prairie associates, the wooded associates and the soils under the influence of woodland invasion of prairie.

(d) The effect of "position" or "relief" and *(e)* the "presence or absence of ground water" is observed in the profiles of the prairie, the meadow-prairie, the meadow, the solonschak and the alkalinized types.

(f) The effect of "age" (or the varying stages of maturity) is noted in the varying phases of alkalinization and degradation, in the transitional soil types, and in the recent alluvial and river deposits. Thus although climate is universally conceded to be the major factor in determining soil type (or soil group) it is apparent that in the Red River Valley Plain, typical zonal or regional soils occupy only a subordinate acreage owing to the extensive tracts of flat topography, imperfect drainage and low relief These factors have been responsible for the extensive development of local soils types with local "soil climates." Large areas containing a number of different soil types, such as the one discussed, show that the assumption of the extensive occurrence of regional soils from inspection of regional climate data may not be justified; consequently a theoretic regional or climatic soil map may be misleading unless qualified The occurrence of soil associates showing such wide morphological differences from the typical regional soils emphasizes the importance of giving due weight to the determining factors other than regional climate, both in soil-mapping and in soil-classification.

CONCLUSIONS

1. Typical regional soils occur in the Red River Valley Plain only in the well drained position with smooth topography where the soil climate is in harmony with the regional climate.

2. Associated with the typical regional soils there are a number of other soil types (or groups) differing widely in their morphological characteristics from the typical regional soils. These associated soil types have been determined by the modifying effect of native vegetation, position, drainage or ground water, which together or singly have been responsible for local soil environment, or local soil climate.

3. The soil types (or groups) which occur in this latitude show that varietal differences occur because of differences in texture and mineralogical composition of the parent material.

4. The varying stages of development of these soils indicate the effect of age, or the length of time that the soils have been under the influence of the various determining factors. In other words the degree of development is a function of age.

5. The occurrence of numerous local and intra-zonal soils associated with the regional zonal soil, in the Red River Valley, form an "area complex" which presents a problem in soil classification. However by considering the soils, not only as units, but as associated members that are under differential environment, the "area complex" is simplified and the relationship of the different soils is easily understood.

REFERENCES

1. Ellis, J. H. A field classification of soils for use in the soil survey. Sc. Agric. *12* : 6; 338-345. 1932.

2. Meteorological Data. Annual Reports of the Meteorological Service of Canada, Ottawa.

3. Thornwaite, C. W. The climates of North America. Geographical Review *21* : 633. 1931.

4. Upham, W. Glacial Lake Agassiz in Manitoba. Geological and Natural History Survey of Canada 1890.

Résumé

Types de sols que l'on trouve dans la plaine de la vallée de la Rivière Rouge. J. H. Ellis, Université du Manitoba, Winnipeg, Man.

Dans la plaine de la vallée de la Rivière Rouge, les sols typiques régionaux ne se rencontrent que dans la partie bien drainée, à contours lisses, où le climat du sol est en harmonie avec le climat de la région. A côté de ces sols typiques régionaux et très différents de ces derniers par leurs caractères morphologiques, se trouvent d'autres types ou groupes de sols qui sont le résultat de l'effet modifiant de la végétation indigène, de la situation, de l'égouttement ou de l'eau du sol; ce sont ces facteurs, qui, ensemble ou séparément, sont la cause déterminante des conditions environnantes ou du climat dans lesquels se sont formés ces sols locaux. Les types ou groupes de sols qui se rencontrent dans cette latitude montrent que les différences de variétés proviennent des différences qui existent dans la texture et la composition minéralogique des matériaux de formation. Les phases variables de développement de ces sols indiquent l'effet de l'âge ou la longueur de temps que les sols ont été sous l'influence des divers facteurs de détermination. En d'autres termes, le degré de développement est une fonction d'âge. La présence de nombreux sols locaux et intrazoneaux associés aux sols zoneaux régionaux, dans la vallée de la Rivière Rouge, forme une région complexe qui présente un problème de classification. Cependant, si l'on considère les sols non seulement comme unités, mais comme des membres associés placés dans des conditions environnantes différentes, le problème présenté par la région est simplifié et les rapports qui existent entre les différents sols sont faciles à comprendre.

SOIL STUDIES IN RELATION TO LAND UTILIZATION RESEARCH[1]

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The regional research programme of the Ontario Research Foundation has required the accumulation and correlation of much data regarding existing soil conditions in Ontario. In some regions the results of soil surveys were available, while in others it was necessary to obtain the required information by some speedier and less costly method, so that our experiences may prove of some interest if only as an expression of the viewpoint of the farmer and the land utilization investigator as to the ultimate objective and value of soil surveys.

A survey of agriculture would seem to indicate that the greatest problem confronting agricultural investigators in this country at the present time is that of interpreting research findings in terms of land utilization and crop production. Immediate action is needed to bridge the enormous gap at present existing between scientific progress and actual farm practice, and the solution of this problem is dependent upon just such opportunities as this for workers to view their work in relation to each others' activities and see individual investigations in their true perspective as contributions to a common objective—the most efficient use of our natural resources.

Periods of economic depression invariably create in the public mind a critical attitude toward existing policies of every nature, and it is becoming increasingly evident that this attitude, arising out of the present crisis, holds great possibilities for the future of agriculture in this country. But it is also true that economic stress has exposed, as prosperity never could, the inherent weaknesses in existing methods and machinery for promoting agricultural efficiency, and we are confronted with a demand for more tangible results from the money spent on agricultural education, extension, and research.

During the period of high prices, agriculturists as well as those responsible for appropriations for research, were satisfied with records of unprecedented expansion in cultivated acreage, great increase in total yields, and outstanding achievements of individual scientists in specific branches of research, such as plant breeding, defence against disease and insects, or soil studies. Being convinced of the potential value of such work, they assumed that actual agricultural practice in this country must be a true reflection of contemporary progress in scientific research. But low prices, and the disruption of international markets, have focused attention upon our actual status as agricultural producers, and revealed the startling fact that in reality a huge gap exists between scientific progress and national efficiency in crop production. It would seem that the very wealth of our natural resources and scientific achievements had led us to accept potentialities for accomplishment.

It is impossible in the limited time available to discuss a problem like land utilization research from all angles, and as crop production is the

[1] Presented at the annual meeting of the Soils Group of the C.S.T.A. at Macdonald College, P.Q., June 26 and 27, 1934.

primary factor in our agricultural development, I shall limit my remarks to this phase of land utilization and shall attempt to discuss as comprehensively as possible in the brief time allotted this problem from the following angles:

(1) The present status of agricultural development in this country;

(2) The inherent weaknesses in our present land utilization;

(3) Accumulated experience vs. scientific research as a means of increasing efficiency in land utilization;

(4) The scope of soil surveys in our regional research programme.

PRESENT STATUS OF AGRICULTURAL DEVELOPMENT IN THIS COUNTRY

In order to gauge the value of any type of soil survey in relation to land utilization studies, one must have a very clear conception of the present status of land utilization in individual countries and of the peculiar problems confronting the investigator in these areas.

It is obvious that methods and policies which meet the needs of one country may be entirely inadequate to solve the land utilization problems of another in a different stage of agricultural development. In young countries, for instance, the accumulation of detailed information regarding the productive potentialities of individual areas is the primary consideration and must preceed sound national planning, while in older countries where these capacities have already been determined by generations of experience, more extensive surveys to serve as a basis for national production policies may be the pressing need. Consequently, if we are to obtain a true perspective of our own land utilization problems we must view them in panoramic relationship to agricultural history. It is only against such a background that present problems assume their true significance.

From this viewpoint, agricultural development in Canada is recognized as a logical outgrowth of two economic forces, both of which have demanded the temporary sacrifice of purely agricultural interests to broader national interests. The first of these was the rapid settlement of a new country, and the second was the abnormal European demand for food during and following the Great War. These two forces have been detrimental to the development of permanently sound land utilization and crop production policies, in so far as they created standards of efficiency which ignored long term considerations

In a young country lacking transportation facilities, the immediate needs of the pioneer rather than the latent capacity of the land for the production of specific crops, determine land utilization. As transportation and industrial centres develop, however, the demands of individual markets and increased competition influence crop distribution. But it is not until a new country actually becomes engaged in international competition, that a truly efficient use of agricultural resources becomes imperative. Efficiency in agricultural practice is consequently a relative factor. The use of land which represents efficiency to the pioneer, when the creation of a homestead is more profitable than a surplus of unsaleable crops, is inefficient when local markets become acces ible, and even more inefficient in the face of international competition. Similarly, the necessity for intensive cultivation, and conservation of soil fertility, which is the essence

of old world efficiency seems less urgent in a country where labour and fertilizers are expensive, and unlimited areas of fertile land are cheap. Thus throughout the early stages of national development, local standards of efficiency in agricultural practice are continually changing. To prove efficient in the long run, however, agricultural practices must be based on an accurate knowledge of the possibilities and limitations of natural agricultural resources, and it is just this accumulated knowledge which is lacking in a young country such as ours.

Agricultural history offers ample evidence that expansion in production to meet the abnormal needs of war has invariably created standards of efficiency in land utilization and cultural practices which have proved inadequate to meet the increased competition of a post-war economy. True agricultural progress, on the other hand, has developed as an aftermath of periods of unusual stress in the industry. Thus the economic depressions following war, rather than the increased demand during wars, have been the impetus to fundamentally sound progress. During our own early days, when land was free and taxes low, or later when foreign competition was eliminated by war, our national standards of productive efficiency were adequate, but we have now reached the stage in agricultural development where we must recognize the universally accepted standards of efficiency—maximum yields per acre at minimum cost of production. While acreage expansion regardless of these standards may have been a sound policy during settlement and war, it provides little basis for permanent agricultural development.

In view of our agricultural history, it is not surprising that our acre yields should be low in comparison with those of older countries of long established agriculture, but it is surprising that in spite of the progress in agricultural science during the last fifty years our average level of efficiency in production has shown so little change. It is disconcerting to realize that with all the aids of modern science at our command we have been unable to equal the increases in yields achieved by older countries during similar periods before the application of science to crop production problems. Not only have we failed to increase acre yields in most crops to any appreciable extent, but those of ten of our common crops have decreased while costs of production have increased.

THE INHERENT WEAKNESSES IN OUR PRESENT LAND UTILIZATION

Nowhere has the depression been more ruthless in exposing weaknesses in agricultural policies than in regard to land utilization. It has precipitated the necessity for immediate readjustments in production policies, and at the same time disclosed the absence of any planned policy of land utilization which would serve as a basis for sound readjustments, now and in the future. It is evident that haphazard readjustment will be futile as a remedy for haphazard expansion; for curtailment of total yields in some crops, expansion in others and transitions in types of farming, all must be accomplished concurrently with a reduction in production costs to meet world competition.

The agricultural history of older countries shows that flexibility in land utilization has been the most logical and effective defence of the

farmer in the face of economic changes over which he had no control. Indeed, that flexibility in production policies which provides a basis for profitable expansion of individual crops when economic conditions warranted, and a sound, even if less profitable, alternative use of land when economic changes forced readjustments, seems to have been an essential factor in agricultural stability. But at the present time we are faced with the necessity for drastic changes in land utilization policies regardless of the fact that our past experience has provided no basis for such flexibility in agricultural production, or alternative uses of land. As pointed out above, our land utilization still largely reflects the pioneer perspective of efficiency, influenced by the false standards created by abnormal demands and prices of war, and neither of these influences in agricultural expansion encouraged utilization policies which would stand the strain of international competition.

ACCUMULATED EXPERIENCE vs. SCIENTIFIC RESEARCH

The dominant factor in agricultural progress in older countries has been the accumulated experience of operating farmers gained through centuries of trial and error. Their national agrarian policies have made possible a continuity of experiment and observation which disclosed the crop production possibilities and limitations, and the best cultural methods for individual holdings, under a great diversity of economic and social fluctuations. For instance, during the Roman occupation, all available arable land in England was devoted to wheat growing to feed the Roman armies in Gaul. Later the withdrawal of this market caused a reversion to more self-sufficing farming, and a great decrease in cultivated acreage. By the middle of the fourteenth century this mode of farming was again giving way, under the pressure of local competition, to specialization and the distribution of crops according to natural adaptability: wheat north of London, from Suffolk to Gloucester; rye in the North; malting barley in Hampshire, Cambridgeshire, etc. From the Roman occupation to the Great War, England has increased cultivated acreage when war or other economic disturbances have created unusual demand or prices, and subsequently returned millions of acres to grass or rough pasture when economic changes made cultivation less profitable; and it is significant that by the middle of the nineteenth century, before agricultural research as we know it had any appreciable influence on the rank and file of British farmers, this accumulated experience in adapting production of various crops to the fluctuating demands of both local and foreign markets, had developed remarkably efficient and flexible land utilization policies. When scientific findings in genetics, soil conservation,. cultural methods, and general agricultural practices became available, they were considered and applied in the light of this accumulated experience, and resulted in an era of unprecedented agricultural progress. .

In a young country such as ours, the acquisition of fundamental agricultural knowledge through such accumulated experience has not been possible. We have had neither the length nor continuity of experience which would disclose the most efficient use of our agricultural resources from the purely agricultural standpoint, and yet our growing dependence upon international markets makes it imperative that we establish a sound

basis for flexibility in land utilization and production policies. But even if it were otherwise practical, the accumulation of knowledge necessary for such flexibility, through individual observation and experiment, would be too slow to meet the needs of a country already vulnerable to the economic disturbances of foreign markets. Consequently, we must depend upon science for acquisition of that fundamental knowledge which accumulated experience has provided for older agricultures. But scientific research can provide a successful short-cut to the accumulations of such knowledge only if those in charge of field investigations maintain the perspective of the experimenting farmer, who sees each problem, not as one in chemistry, physics, genetics, or pathology, but as one in efficient utilization of a definite coincidence of agricultural resources. It is this perspective which has been responsible for the ultimate success of the trial and error system in evolving essentially sound agricultural principles throughout the ages, in spite of the great waste of effort and money such repetition of experiment involved.

Scientific research could accomplish in this country in a comparatively few years, that which has taken centuries in the older countries, but only if we recognize the significance of specific and detailed knowledge in agricultural progress. Unless research findings are related to actual growing conditions under which the farmer operates, and are interpreted in terms of practical farm procedure, scientific research cannot replace individual experiment. And in the final analysis the value of land utilization studies in this country must be gauged by their capacity to reduce the necessity for this wasteful repetition of individual experiment.

"Land utilization" as generally used is a misleading term, because what we really mean is utilization of agricultural resources. Land in itself possesses no potentialities for agricultural production apart from the other factors with which it is associated in individual environmental coincidences, neither do individual crops or varieties possess potentialities for yield, quality, or resistance to disease or parasites except in relation to these interrelated factors. Consequently, successful crop production is dependent upon the adaptation of individual plants to a specific coincidence of factors of which soil is only one.

But the limitations of our present academic system demand the artificial subdivision of agricultural science into isolated departments. Limited time and funds force the individual student to specialize and consequently emphasize these divisions. The student who turns to practical farming, immediately proceeds to interpret all his unrelated knowledge into terms of crop production under specific conditions, but the graduate who enters the research field, is often not sufficiently impressed with the fact that such divisions are primarily for academic convenience, and must not be allowed to distort the perspective of the land utilization investigator who must view every problem in crop production as one in the adaptation of plant growth to a specific environmental coincidence, and one which will require for its solution collaboration of specialists in many branches of agricultural science.

The necessity for individual specialization, sometimes obscures the fact that the solution of an isolated problem is not an end in itself, but a potential contribution to the major problems of increasing our efficiency

in the use of agricultural resources. While background and breadth of perspective are chiefly valuable in those responsible for research policies, we must realize that the helper of today is the director of tomorrow, and that breadth of vision will not develop automatically with change of office. The too early specialization of agricultural investigators tends to widen the gap between scientific and practical progress.

THE SCOPE OF REGIONAL RESEARCH

As we have noted above, an outstanding feature of our agricultural development is the failure of farm practice to reflect contemporary progress in the individual branches of agricultural science. This is due chiefly to the following factors:

(1) That habit and tradition have crystallized pioneer practices.

(2) Inadequate provision for that co-ordination and interrelation of isolated findings which are necessary before they are applicable to crop production problems.

(3) That although blanket recommendations are of little value under our great diversity of growing conditions, the individual growth coincidences to which more specific recommendations must be related have not been defined either by fundamental research or accumulated experience.

Consequently, the publication of findings in individual branches of agricultural research, increases, rather than decreases, the necessity for individual farm experiment. To be effective as a means of increasing average production efficiency, scientific findings regarding individual crops must be considered in relation to definite environmental coincidences, while findings regarding light, soil, fertilizers, disease, etc., must in turn be considered in relation to individual crops and varieties in specific environments. Unfortunately, neither the specific coincidences under which growth must proceed throughout this country nor the specific reactions of individual crops and varieties to these growth coincidences have been defined.

It was in an effort to define these growth coincidences which determine our agricultural potentialities, and so provide a basis for effective application of scientific findings to crop production on the individual farm, that the regional research programme of The Ontario Research Foundation was planned. The principles and objectives of this programme have been outlined in a previous publication (*1*). It is essentially an effort to bridge the gap between science and practice, and thus reduce the wasteful repetition of experiment on individual farms. It aims to provide a foundation for sound land utilization policies through co-ordination of many unrelated detailed investigations, and so to combine the speed and accuracy of modern science with the fundamentally sound perspective of the old trial and error system. The possibilities for economy of time and effort inherent in such co-ordinated attack of land utilization problems is evident, but, as noted above, success in operation is dependent upon the ability of investigators to collaborate.

In a country as vast as Canada, with such diversity in type and distribution of agricultural resources dependent for development upon international markets, any provincial research programme must be sufficiently fundamental to form a basis for collaboration with other provinces in the

institution of national production policies. Our present trend towards national marketing must inevitably result in the consideration of production policies from a national standpoint, in spite of the fact that political considerations demand that many agricultural research projects be provincial in scope.

The two systems of agricultural research most commonly employed are subjective and regional. The first confines investigations to specific problems whose solution is of general significance, such as plant breeding or plant pathology. The second confines investigations and relates findings to definite political areas, usually counties in the province of Ontario.

In order, therefore, to interpret individual research findings in terms of actual farm procedure under specific coincidences of crop and environment, it is necessary to correlate these two types of research in a definite plan. For instance, the development of new varieties holds great possibilities, but their successful distribution must be based on a knowledge of their capacity for yield, quality, and resistance to disease under all the environmental coincidences throughout the country, not only the one in which they have been developed.

Owing to the fact that the political units, such as counties, have no agricultural significance, the boundaries of our units for regional research have been determined by ecological conditions, and the findings of subjective investigations are considered in relation to the accurately defined characteristics of those units. Such correlated findings provide a basis for profitable land utilization and crop production in any region. Where comparisons of two regions reveal duplications of growth coincidences, we may assume that results obtained in one would be repeated in the other and thus eliminate repetition and overlapping of research work.

Our regional research studies are an attempt to co-ordinate research, in recognition of the following principles:

(1) That our agricultural progress will be in proportion to our skill in using the agricultural resources at our command;

(2) That these resources consist of definite coincidences of environmental factors which scientific investigation can define,

(3) That individual crops and varieties demand definite coincidences of environmental factors for successful yields at minimum cost;

(4) That correlation of all research in relation to the growth of individual crops in specific environments is the only sound basis for those readjustments in land utilization and farm practices which changing economic and social conditions make necessary.

SOIL SURVEYS

From such a viewpoint, the ultimate value of any type of soil survey must be gauged by its capacity to contribute to the farmer's knowledge of his own crop production possibilities and limitations. It would seem that the greatest weakness in many of our present systems is the perspective which regards a soil survey as an end in itself, and fails to provide for its interrelation with other factors affecting agricultural use. The fallacy of assuming that soil types, or subtypes, in themselves possess consistent potentialities for crop production or other agricultural use, apart from

the environmental coincidence with which they are associated in different agricultural areas, cannot be too strongly emphasized. Findings regarding individual soil types must be correlated with a knowledge of other factors such as topography, temperature, moisture, and light before such findings possess any value as indicators of crop production possibilities. For instance, a soil type which is extremely valuable for peach production when associated with the climatic conditions of the Niagara Peninsula below the escarpment may be almost worthless when situated on top of the escarpment a mile distant where peach trees will survive, but because of slight deficiencies in temperature will not bear consistently. Variations within one soil type, even so slight as a few degrees difference in soil temperature at root depth, may greatly change its value for production of a single crop, while differences in the agricultural history of adjoining fields may result in great diversities in physical and chemical characteristics and in productive possibilities.

In settled agricultural areas, experience and tradition prevent gross misuse of soil types. In the Niagara Peninsula, for instance, experience has proved the superiorities of certain soil types for peach or cherry orchards as well as the most profitable use for the heavy soils in this climate, and crops are generally distributed on this basis. But the enormous diversities in yields of various crops on a single soil type throughout a region where other factors are remarkably uniform, indicate that minor variations in depth of soil, soil temperature, topography, etc., within single soil types are as potent as distinct differences in type in affecting productivity of individual crops. That lack of definite knowledge regarding the distribution of these variations and their effect upon plant growth has been responsible for much misuse of land. Recent investigations have shown that not only poor yields of peaches and short-lived orchards, but heavy losses from specific diseases, have been consistently associated with minor variations in a single soil type thought to be normally optimum for peach growing.

Soil specialists are agreed that one of the major difficulties confronting those planning soil surveys is to decide upon the amount of detail which should be included. If surveys are to be dependable as a basis for land utilization, even the slightest variations in soil types cannot be overlooked. It is obvious that any attempt to map accurately the distribution of all variations in types and sub-types of soil in farming areas of such diversity as ours would be impractical at the present time. Neither is there any uniformity in the chemical or physical characteristics of a single type, even within one region. And yet it is just such specific information which is required by the farmer if science is to replace trial and error on the individual farm.

It is extremely valuable for statistical purposes and national planning to know the approximate extent and distribution of various soil types, but such general and unrelated information is of little value to the farmer confronted with an actual problem in land utilization. Therefore, the value of available soil maps, in relation to immediate land utilization studies in most areas, must be general rather than specific. For instance, when all types and sub-types in a region have been isolated by a soil survey, and each of these considered in relation to the major environmental factors, it is a

relatively simple matter to offer general recommendations as to the most profitable uses and methods of culture for definite variations within this area. But under our present system of soil mapping, success in applying these general findings is still dependent upon the ability of the farmer to identify slight variations in his own soil types, and upon individual experiment to determine the presence and effects of variations in physical and chemical characteristics. Consequently, we concluded that from the standpoint of determining crop production potentialities on individual farms, the chief value of existing soil surveys lay in the isolation and identification of the various types and sub-types present in any region. But we also discovered that these essential data could be secured in a fraction of the time by other methods and thus obviate the necessity for delay in those regions where soil surveys had not been completed. Comparisons of records showed that a study of numerous crosscuts of a region isolated all the types and sub-types revealed by the more detailed survey, and in a fraction of the time, although it did not determine the extent or distribution of each. It is not the desire to discredit detailed soil surveys—such information is essential for institution of general policies, and national planning but in our immediate objective of providing the individual farmer with accurate knowledge of his own conditions it has little, if any, advantage over speedier and less costly systems. Moreover, the necessity for immediate readjustments in use of land in this country makes it impossible to delay this phase of land utilization work until complete detailed soil surveys of all regions are available.

Having found soil maps impractical as a means of delineating the variations of soil types on individual farms, it seemed that the most logical alternative was to assist the farmer in identification of his own types, and to provide him with definite information as to the best use of each under his own conditions. Consequently, soil profiles of all types are being

FIGURE 1.—A group of soil profiles used to illustrate soil types to farmers.

prepared, and are on exhibition accompanied by paintings showing natural coloring before exposure. All general findings applicable to the entire region, regardless of soils, are filed as regional, while the data applicable to a specific soil type wherever found in the region are filed in relation to that definite coincidence of factors.

Investigations to determine the optimul conditions for productivity of individual crops and varieties, and the reaction of plants, cultivated and wild, to the various coincidences of factors present in each region, are carried on concurrently with the more general regional work. Consideration of all findings in their interrelation indicates the most profitable present use of land and also provides a basis for alternative uses should need arise. It has been the practice in many soil surveys to label certain agricultural areas as marginal or submarginal and advocate their abandonment or reforestation. There have undoubtedly been mistakes in land settlement all through this country, and it is only reasonable that every effort should be made to isolate less productive areas and to settle the best agricultural land first. Nevertheless, in all land utilization studies it is essential to recognize the fact that some lands judged sub-marginal by one generation of farmers have proved highly profitable in another under different economic conditions and improved agricultural methods. For this reason it is important that no partiality be shown in thoroughness of regional investigations and that detailed information of all areas should be on file as a basis for future readjustments.

The proposed soil survey according to genetic types will be a valuable source of data when complete. But great economy in agricultural research could be effected if greater co-ordination were maintained between soil surveys and other relevant researches. For instance, if all regional investigations in meteorology, ecology, agronomy, pathology, entomology, etc., could be carried on simultaneously with soil surveys, much repetition of research to determine the effects of soil variations upon plant growth and crop production in individual areas could be avoided.

By recording all findings in relation to specific coincidences of environmental factors which have been accurately defined, we are building up a permanent structure of correlated fundamental information which will serve as a basis for application of all relevant research findings of the future, and thus reduce the necessity for individual experiment.

REFERENCE

1. JARVIS, T. D. The fundamentals of an agricultural research programme. Sci Agr. *12* : 92-114. 1931.

ABSTRACTS

SOIL SURVEY BY PLANT ANALYSIS. Andrew Dingwall, Research Spectroscopist, Columbia University, New York City.[1]

In the past soil survey has been confined to two types of work viz.:—field soil classification and chemical analysis to determine the chemical contents of the soil. It was suggested that a new type of survey be made based on the analysis of plants grown on the soil under investigation. Samples of soils and plants grown in the province of Quebec were submitted to spectrographic analysis and the spectrograms projected and discussed before the meeting. It was shown, for example, that there was no correlation between the quantity of chromium present in the soil and the quantity in the plant. Other elements such as molybdenum, manganese, iron, copper, strontium, barium, lithium, rubidium, and so forth, were discussed.

It was further pointed out that in the future soil surveys must take into consideration the nature and the quantity of elements found in the plant with regard to their possible influence on public health. As an example, it was shown that in certain localities the plants were relatively rich in lead and it was suggested that the ingestion by humans or livestock of large quantities of leafy plants grown there might become a health hazard. The finding of molybdenum in certain muck soils raised the question of the effect of molybdenum on the animal economy.

[1]This paper, read at the June, 1934, meeting of the Soils Group C S T A., was published in part in the Canadian Journal of Research *11* 32-39, July 1934, "Studies on the Distribution of Molybdenum in Biological Material 1 A Spectrographic Study of the Occurrence of Molybdenum in Plants Grown in the Province of Quebec," by Andrew Dingwall R R McKibbin and H T Beans

ORGANIC MATTER AND ACIDITY IN PODSOL SOILS. H. J. Atkinson, Macdonald College, Quebec.[1]

Leached with distilled water, the raw humus of the A_1 horizon of Quebec virgin podsols gave percolates of gradually increasing pH values over periods of 14 weeks, beginning in two instances at 4.3 and rising to 5.4, and in a third at 3.8, rising to 4.8. When concentrated by evaporation to one tenth or one twentieth of the original volume the percolates retained 83.5 to 99% of their total acidity. The concentrates were fractionated by dialysis through cellophane. From 46 to 91% of the acidity dialyzed. In five soils, 47.5 to 56.4% of whose acidity dialyzed, total sulphuric acid amounting to 30 to 52% of the total acidity, was found in the dialyzate. The free (alcohol-soluble) sulphuric acid amounted to 9.5 to 23% of the total acidity of the percolate. Phosphoric acid was present in mere traces in some samples but in one instance the total phosphoric acid content was sufficient to account for 28% of the total acidity, if it is present in the free state.

[1]This paper, read at the C S T A Soils Group meeting at Macdonald College, June 1934, was published as follows. Chemical Studies on Appalachian Upland Podsol Soils, II Organic Matter - Acidity Relations H. J. Atkinson and R R McKibbin Can. Jour. Res *11*: 759-769 December, 1934

THE RATIO METHOD OF COUNTING SOIL BACTERIA. P. H. H. Gray, Macdonald College, Quebec.[1]

This paper was descriptive of a method developed at Rothamsted for determining the number of bacteria in soil by means of stained films, in which a known number of microscopic particles of indigo have been dispersed.

Tables were presented showing that the method can be relied upon to give close agreement between different workers and parallel samples of soil. The numbers of bacteria (to be precise, cells identified as bacteria, with the reservation that some of them may be those of actinomyces) in certain soils were also shown in a table, in which the ratio of the total cell count to the plate count was also presented. By means of diagrams it was shown that bacterial numbers may be correlated with crop yield, and that significant differences in numbers in a single plot of field soil may occur within a few hours.

[1]This paper, read in June, 1934, at the C S T.A. Soils Group meeting, was published in full in the Proceedings of the Royal Society of London, Series B, No. 795, vol. 115, pp. 522-543, August, 1934. "The Numbers of Bacterial Cells in Field Soils, as Estimated by the Ratio Method," by H. G. Thornton and P. H. H. Gray, with appendix by R. A. Fisher.

L'UTILITE DE LA CARTE AGRONOMIQUE[1]

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Il serait certainement téméraire de dire que l'étude du sol en relation avec la plante est aussi ancienne que les autres sciences. Le sol était sans doute trop près de l'homme pour que celui-ci fût porté à s'en occuper.—Il n'est pas nécessaire pour constater ce fait de remonter aux temps anciens où la richesse ne consistait pas tant en biens fonds qu'en nombreux troupeaux. Même au commencement du vingtième siècle le sol intéressait si peu les scientistes qu'on le considérait encore comme une branche de la géologie. En effet, il y a à peine une trentaine d'années, on considérait le sol comme du roc réduit en poussière plus ou moins fine, à la surface de laquelle, s'était accumulée une certaine quantité de matière organique. On croyait qu'un sol formé de roches calcaires était toujours riche en chaux, qu'un autre formé de roches pauvres en acide phosphorique devait nécessairement être pauvre en cet élément. Avec le concept que l'on avait des sols, il suffisait donc de connaître les roches qui leur avaient donné naissance, pour être fixé sur les propriétés de ceux-ci.

Mais voici que vers 1914 les pédologistes russes firent connaître au monde scientifique les résultats de leurs travaux de recherche sur les sols. C'est alors que l'on vit que le facteur principal était le climat qui placait la roche effritée dans certaines conditions de température, de végétation, de précipitation, etc., lui apportant des caractéristiques totalement différentes. C'est ainsi qu'un sol granitique, formé dans la province de Québec, ne ressemble pas à un autre sol de même origine, mais formé au pôle nord ou dans les provinces des Prairies.

Si le sol est le produit des conditions environnantes, on ne peut donc guère acquérir de connaissances précises à son sujet qu'en l'étudiant dans son milieu. C'est ce en quoi consiste le travail de classification des sols et de la carte agronomique.

Cette étude du sol sur place est certainement un travail long et dispendieux. Les avantages que l'on est en droit d'attendre sont-ils suffisants, pour justifier un tel travail? C'est ce que nous nous proposons de démontrer en indiquant les services que ce travail pourrait rendre aux particuliers comme au peuple canadien.

I

Les données fournies par le rapport de la classification des sols, dit Milton Whitney (3) sont la base fondamentale de l'organisation des systèmes de culture d'une ferme; les générations présentes et futures doivent en bénéficier.

Qu'un cultivateur change de région ou qu'un citadin veuille s'établir sur une terre, ils verront dans ce rapport une aide précieuse (15) qui les empêchera d'être induits en erreur par les personnes qui sont intéressées à les voir se diriger dans telle région particulière. Veulent-ils se choisir

[1] Travail présenté à la réunion annuelle du Groupe des sols de la C.S.T A. tenue au Collège Macdonald, P.Q., les 26 et 27 juin 1934.

une région avec l'intention d'y pratiquer une certaine culture, ils verront par le rapport si la partie de terre convoitée répond bien à leur désir. Celui-ci leur dira que dans tel endroit, c'est telle culture qui est la mieux adaptée, ou tel mode d'exploitation qui est en honneur.

Supposons que l'on veuille diriger un groupe de colons sur une région particulière: si l'on avait une classification des sols, on pourrait leur donner des renseignements précis sur la valeur du district, ses possibilités agricoles, l'éloignement des centres importants, les facilités de communication, etc. Ils auraient une idée assez juste de la région qu'ils convoitent, même sans l'avoir visitée.

Le cultivateur émigrant n'est pas le seul à retirer des bénéfices de la classification des sols, celui qui reste attaché à la succession de ses aieux y trouvera également de précieux avantages.

Voici qu'un bon jour ce cultivateur s'aperçoit qu'avec les méthodes de culture de son arrière-grand-père, il ne peut réussir à joindre les deux bouts. Que faire s'il ne veut pas être obligé de vendre sa terre? Adopter un meilleur système de culture? Mais quel sera ce système? S'il n'y a pas de classification des sols dans la région, l'agronome pourra bien lui donner de sages conseils, mais sa besogne sera bien simplifiée s'il a entre les mains la carte agronomique de la région. Avec cette carte, il pourra situer la ferme en question et voir les types de sols qui la composent. Le rapport lui dira ensuite le point faible de cette ferme. manque d'éléments de fertilité, mauvaises conditions physiques, mauvaise adaptation des plantes aux sols, mauvaises cultures pour les exigences du marché, etc. En touchant du doigt le point faible, il sera plus facile d'y remédier; c'est ce que l'on a fait en maints endroits de la Saskatchewan (11) et les résultats sont très probants.

Il pourra comparer le sol de sa ferme avec celui d'autres régions plus prospères, situées sur un sol d'un même type; il verra s'il y a lieu de changer son système dù culture ou d'adapter certaines cultures spéciales. En effet, avec le rapport, dit J. A. Bonsteel (14), l'horizon d'observation du cultivateur se trouve beaucoup élargi et il peut bénéficier de l'expérience des cultivateurs d'autres régions.

La rive est de la Baie Chesapeake, dans le Maryland et le Delaware, est une région ou la culture du blé et du blé-d'Inde ne réussissait pas. Les cultivateurs étaient pauvres et tout annonçait la misère. Les études faites après la classification des sols montrèrent que cette région serait bien adaptée pour la culture des petits fruits. L'introduction de ces récoltes révolutionna complètement la région et aujourd'hui nous y trouvons des cultivateurs prospères (12).

La même chose peut se constater dans le comté de Norfolk en Ontario, avec la culture du tabac.

II

Ces services rendus aux cultivateurs par la classification des sols méritent sûrement d'être considérés, mais les avantages de la classification des sols sont plutôt d'ordre général.

Pour mieux apprécier ces avantages généraux, nous jetterons un coup d'œil sur l'utilité de la classification au point de vue national, au point de vue colonisation et au point de vue agricole.

FIGURE 1. C'est le manque de classification qui a fait défricher des terres aussi rocailleuses que celle-ci. L'epierrement demande plus de travail que le défrichement. C'est une terre sablonneuse, plutôt pauvre

Lack of an adequate soil survey permits the clearing of rocky land, such as shown. This clearing requires much labour and leaves the settler with poor gravel soil.

FIGURE 2. Colonie nouvellement ouverte par la Société de Colonisation de Québec: Ste-Anne de Roquemaure, Abitibi. A noter l'absence complète de roches; c'est une belle terre argileuse.

New colony established by the Colonization Society of Quebec; Ste. Anne de Roquemaure, Abitibi. Note the complete absence of stones, this is a good clay soil.

Le rapport de la classification des sols, en nous donnant un aperçu si détaillé sur les conditions du sol, n'est autre chose qu'un inventaire détaillé des ressources du pays. Il localise les cours d'eau, les chemins de fer, les routes, etc. Il peut venir en aide aux ingénieurs, pour l'établissement de nouvelles routes, car il indique la topographie du terrain, l'éloignement des autres chemins publics et l'emplacement de la matière première pouvant servir à la construction de ces routes, comme le gravier, le sable, etc., etc.

Une connaissance précise des sols peut être très précieuse pour la construction de nouvelles routes ou l'amélioration des anciennes. Un classificateur expérimenté, qui connait bien le sol dans ses conditions naturelles, dit W. I. Watkins (7), peut facilement trouver les causes de la détérioration de certaines routes au printemps et y trouver des remèdes.

Le rapport nous donne aussi une idée de la condition sociale des habitants, de leur richesse et de leur instruction, car il nous dit assez bien ce que valent les terres et les troupeaux, et la carte agronomique nous montre les sites des écoles, des églises ou d'autres bâtisses d'utilité publique. En un mot, comme le dit C. B. Williams (2), la classification des sols sert comme référence générale.

L'industrie pourrait également retirer de précieux avantages de cette classification, car elle donne une description détaillée et exempte de préjugés des ressources (15) d'une région. Les entreprises industrielles qui dépendent directement du sol (16), pour obtenir leurs matériaux bruts, comme la glaise, la pierre à chaux, la marne, etc., y trouveraient de précieux renseignements pour la réussite de leurs affaires.

Les banques et les compagnies de prêts agricoles trouveraient également de précieuses indications dans le rapport de classification, pour déterminer la valeur des terres et pour consentir des prêts aux cultivateurs. Comme le fait remarquer Charles H. Seaton (15), les compagnies de prêts trouvent dans ce rapport des renseignements précieux quand elles veulent consentir des avances sur certains sols de telle région.

Aux Etats-Unis, les compagnies d'assurance (3) se servent de la carte agronomique, pour déterminer l'état sanitaire d'une contrée, car, dit R. Harcourt (3), la santé et le bien-être d'un peuple sont en relation intime avec le sol: sur tel sol on trouvera tel degré de confort et progrès.

La classification des sols rend encore de précieux services dans l'établissement du rôle d'évaluation, pour le paiement des taxes. En effet, le rapport indique clairement la valeur des différents sols d'une même paroisse; il ne reste plus aux évaluateurs qu'à déterminer la valeur des bâtisses.

Le professeur Hansen (11) trouve que ce système promet de donner de très bons résultats pour la taxation des terres de la Saskatchewan.

Un autre point de vue qui n'est pas à négliger, c'est le point de vue colonisation. En effet, la classification des sols nous donne une idée précise de la valeur du sol et de son développement possible dans l'avenir. Il est nécessaire, dit Hugh H. Bennett (2), pour notre bien-être et celui des enfants de nos enfants, de ne pas défricher des terres qui conviendraient davantage à la forêt. Il a été commis bien des erreurs dans ce domaine: certaines terres ont pu produire pendant quelque temps, sous la poussée

des cendres du défrichement, mais maintenant elles sont presqu'incultes, et par conséquent représentent une perte pour le domaine forestier et agricole.

Avant de pousser des colons dans une région, ou les laisser s'y implanter, il faudrait voir à ce que le sol puisse les faire vivre, sans qu'ils soient obligés de recourir à d'autres ressources pour pouvoir obtenir leur subsistance. C'est le rapport de classification des sols qui dira si les sols que l'on destine à la colonisation pourront faire vivre leur propriétaire une fois le bois parti (8). Plusieurs fermes du Michigan ont été abandonnées (2) durant les années qui ont précédé la crise actuelle; la classification de ces sols a montré que toutes ces fermes appartenaient à des sols classés, comme improductifs ou peu productifs.

Il est très important de connaître la productivité des différents sols d'une région; mais il est encore plus intéressant de connaître la superficie de chacun d'eux. Ceci est surtout important lorsqu'il s'agit d'ouvrir une nouvelle région à la colonisation. Il peut arriver qu'en un endroit donné, il y ait des terres très fertiles, mais en quantité restreinte, et entourées d'autres terres pratiquement incultes. Devrait-on les défricher? Certes non, car les quelques propriétaires de ces sols fertiles pourront bien avoir de belles récoltes, mais dans quelle situation sociale se trouveront-ils? Entourés de forêts ou de malheureux colons qui ont vu s'écrouler avec chaque arbre une parcelle de leur espoir déçu.

S'agit-il de fonder une nouvelle région, la classification servira de guide pour choisir les meilleures terres d'abord, pour prendre ensuite les moins bonnes, lorsque les conditions se seront améliorées. De même le colon en ayant une idée exacte du fond de la terre, pourra choisir une région où le sol conviendra le mieux à ses aspirations futures.

En plus de ces facteurs, qui regardent directement le sol, la classification peut donner d'autres indications qui affecteront grandement la valeur des terres. Ainsi elle montrera les voies de communication par terre ou par eau, les marchés et les conditions de la région; elle nous donnera aussi une idée du climat, de la topographie, de la population et des industries locales.

Toutes ces indications contribueront à améliorer cet état de choses que déplorait I. D. Rice (2): "Ceux de nous qui ont travaillé à la classification des sols ont pu voir les luttes pénibles de bien des pionniers, qui ont dépensé les plus belles années de leur vie sur un sol improductif, tandis qu'il y avait tout près d'eux des sols fertiles sur lesquels ils auraient pu tout aussi bien s'établir.

Nous avons vu les principaux avantages que l'on peut retirer de la classification des sols au point de vue national et colonisation; les services qu'elle pourrait rendre dans le domaine agricole ne sont certainement pas moindres. La classification, dit le professeur R. Harcourt (3), constitue un inventaire complet des sols; elle a la même raison d'être en ce qui concerne les ressources du sol que l'enquête géologique en ce qui concerne nos ressources minérales. En effet, la classification des sols nous donne un rapport détaillé des différents sols; entre autres renseignements, elle nous donne une idée précise des différentes propriétés de chaque sol.

La productivité d'un sol est en relation très intime avec ses propriétés physiques et chimiques. Qu'est-ce que nous dit la classification des sols

à ce sujet? Par l'analyse mécanique, mentionnée dans le rapport, nous connaissons la grosseur des particules; nous voyons si nous avons affaire à un sol sablonneux ou argileux. Ceci est très important, puisque le sol sablonneux, en contenant la même quantité d'éléments nutritifs, sera toujours moins productif que le sol argileux.

L'égouttement, qui a une si grande importance sur la productivité d'un sol, est encore très bien indiqué dans le rapport.

La topographie joue aussi un certain rôle sur la valeur d'une terre; un sol très accidenté sera plus lavé par les eaux et par conséquent les éléments nutritifs les plus solubles auront une tendance à s'épuiser plus rapidement. Dans certains cas, les accidents de terrain pourront empêcher la culture d'une terre qui par ailleurs serait très productive. La topographie du terrain est encore très bien indiquée dans le rapport de la classification des sols.

Le rapport indique encore la composition chimique du sol. Cette analyse ne donne pas beaucoup d'indications sur le pourcentage des éléments fertilisants utilisables, mais quand elle est complétée par l'étude de la végétation et l'analyse mécanique, elle a certainement beaucoup plus de valeur.

Si l'on rapproche ensuite ces résultats des données que l'on a par ailleurs sur les procédés de formation du sol et sur la nature des éléments qui ont servi à le constituer, on est assez bien en mesure d'en connaître exactement la valeur productive.

Une fois que l'on connaît d'une façon aussi précise ces différentes propriétés, il est beaucoup plus facile de faire des expériences qui pourront être valables pour tous les sols du même type. La grande valeur du rapport, dit R. Harcourt (3), repose dans ce fait qu'il forme la base des études pratiques et systématiques des problèmes du sol.

Si l'on pouvait baser sur le rapport de classification des sols toutes les expériences que l'on poursuit en agriculture, tant dans l'Ouest que dans l'Est, on serait en mesure de tirer de bien meilleures conclusions de ces expériences. On saurait que les résultats de certaines expériences s'appliquent très bien sur telle ferme, mais s'appliquent moins bien sur telle autre, parce que son sol n'est pas le même que celui où s'est poursuivie l'expérience.

On pourrait encore se baser sur ce rapport pour l'établissement des stations expérimentales ou des champs de démonstration. Cela permettrait de varier l'importance des stations avec l'importance des types de sols, sur lesquels elles sont situées. Chaque région aurait sa station de première importance, située sur le type de sol le plus important, avec des sous-stations situées sur les types de sols les moins importants. Les résultats que l'on obtiendrait des expériences faites dans ces conditions permettraient de donner des conseils beaucoup plus précis aux cultivateurs de telle ou telle région en particulier.

Quelques résultats des expériences conduites dans divers états américains suffiront pour prouver cet avancé. J. Wilder, dans un manuscrit inédit "The Apple Soils of New-York" constate que certains sols, dans le même district de New-York, portent des pommiers donnant une "Rhode Island Greening" verte, tandis que d'autres produisent une "Rhode Island

Greening" jaune. Il a trouvé également que le meilleur sol pour la Greening n'est pas celui qui convient le mieux pour la Baldwin ou d'autres variétés.

Des expériences semblables ont été faites à l'université d'Illinois (2) On a établi des champs d'expériences sur différents types de sol, sur lesquels on pratiquait divers systèmes de rotation, avec les plantes usuelles de la région. Certains types montraient leur défectuosité dans la production, soit de l'avoine, soit du soja, tandis que d'autres se révélaient très bons producteurs de maïs, d'avoine, etc.

Ces expériences nous montrent donc que chaque type de sols montre des préférences marquées pour telle ou telle plante en particulier. En effet, la classification des sols, dit L. F. Gieseker (17) nous a rendu de grands services en montrant l'adaptation de certaines aires pour la production de certaines récoltes et en empêchant la répétition des désastres qui se sont produits sur certaines terres pauvres.

C'est cette classification qui a rendu possible en Illinois la fondation d'écoles de fertilité du sol. Les cultivateurs sont réunis en différents endroits, où des experts discutent avec eux leur système de culture, l'avantage qu'ils auraient à adapter tel ou tel autre, la quantité et la qualité d'engrais à employer, etc. Cette méthode d'enseignement, dit E. E. DeTurk (2) a réussi à réveiller même les plus endormis. C'est là qu'on leur indique que, si les fertilisants ne donnent pas les résultats qu'ils devraient donner, c'est à cause d'une mauvaise connaissance du sol (5).

Une connaissance si exacte de nos sols et les données expérimentales sur l'adaptation des plantes aux sols, serait également très utile, pour l'étude des sols dans les différentes institutions agricoles du pays. L'étude des sols serait certainement rendue plus intéressante si l'on pouvait dire que dans telle province il y a tel sol possédant des propriétés particulières que les podsols, si nombreux dans Québec, font place aux tschernosems dans telle ou telle province de l'Ouest.

Pour résumer, nous pourrions dire avec le Professeur Hansen, de Saskatchewan (11): La classification de sols est une chose fondamentale. Pourquoi le cultivateur n'en connaîtrait-il pas aussi long sur son sol qu'il en connaît sur les animaux et la mécanique? Si le développement et la prospérité d'une région dépendent du sol pourquoi ne pas chercher à connaître ce sol à fond; ou encore avec R. S. Smith (16) que la classification des sols fournit une richesse de renseignements qui permettent l'utilisation adéquate des terres.

Résumé et conclusion

Nous voyons donc que la carte agronomique peut rendre de réels services aux cultivateurs canadiens. Elle les guide dans le choix des régions; elle leur dit avec exactitude, sans parti pris, la valeur du sol convoité et les cultures qu'on y pratique. Elle éclaire également le cultivateur qui veut améliorer sur sa ferme son système de culture et lui permet de profiter de l'expérience des cultivateurs, ayant des sols semblables, mais situés dans des régions différentes.

Comme la classification des sols est un travail de grande envergure, elle profitera surtout à la nation. C'est pourquoi nous avons montré

que la classification sera surtout avantageuse, au point de vue national, en faisant l'inventaire complet d'un pays, au point de vue colonisation, en concentrant l'effort des colons, sur des terres qui sont réellement propres à la culture, et au point de vue agricole, en permettant une adaptation plus adéquate de la plante aux différents types de sols.

Ces avantages au point de vue théorique trouvent leur application dans la pratique. Qu'il nous suffise, pour appuyer cet avancé, de rappeler l'enquête que faisait le Dr. Auguste Pépin, en novembre 1921. Il envoya aux agronomes de l'état de New-York, une lettre circulaire leur demandant ce qu'ils pensaient de la carte agronomique. Les réponses qu'il a reçues sont presque unanimes à vanter les bénéfices que l'on peut retirer de ce travail.

Est-ce que ce travail est assez avancé au Canada, pour que l'on puisse espérer en retirer tout le bénéfice que nous venons de mentionner? Il serait difficile de répondre dans l'affirmative, du moins pour Québec, les Maritimes et certaines provinces de l'Ouest.

Mais permettez-moi de formuler, en terminant, un vœu: que la Groupe des Sols de la C.S.T.A., organisé par le professeur Joel, secondé par le professeur Ellis, son digne continuateur, parachève aussi rapidement que possible, la carte agronomique commencée l'an dernier.

References

1 Journal d'agriculture (Québec) Vol. 29 No. 1—Petites opinions à répandre. *Charles Gagné.*

2 Journal of the American Society of Agronomy, Vol 16 No 7—July 1924.
(*a*) The nature of Soil Survey in our National Agricultural Policy. *Milton Whitney.*
(*b*) Difficulties in Utilizing the work of the soil survey. *A. R. Whitson*
(*c*) The relation of the Soil survey to the settlement of unused lands. *Thos. D Rice.*
(*d*) The relation of the soil survey to the utilisation of Southern Soils. *Hugh H. Bennet.*
(*e*) The value of the soil survey as a basis for soil studies and soil use.
(I) In studies of soil properties *M M. McCool*
(II) In experimental work in soil management and uses. *F. F. DeTurk.*
(III) In the teaching of soils in college. *Firman E. Bear.*
(*f*) The utilisation of the soil survey in crop experimental Works. *W. L. Burlisaon* and *C. A. Mooers.*
(*g*) How the soil survey is proving most valuable in North Carolina. *C. R. Williams.*

3 Preliminary soil survey of Southern Ontario, Bull , 298. *R Harcourt, W. L. Iveson, C. A Cline.*

4 Proceeding of the American Society of Agronomy Vol. I, 1910. Value of the field study of soils. *G. N. Coffry.*

5 Das Superphosphat 9, 1933.
Soils Maps, reaction maps and phosphoric acid maps as a basis of the setting up of fertilising and tillage plans in Feldmard *E. Pfuhl.*

6 The American Soil Survey Association, Report 10. Bull XI.. 1930.
The value of research in connection with soil survey *P. E. Brown.*

7 The American Soil Survey Association, Report 13, Bull. XII.. 1931. *W. I. Watkins.*

8 The American Soil Survey Association, Report 12, Bull XIII. 1932.
Soil Survey and Forest Practice. *S. A. Wilde.*

9 The American Soil Survey Association, Report, 14 Bull. XV. 1934.
Land Use and the soil survey in Illinois. *R S. Smith.*

10 The Georgia Soil Survey Bull. 299. *M. W. Lowery.*

11 The Public Service Monthly (Regina (Sask.) March 1923.

12 Lingman Science Journal Vol. 12, Suppl. 1933.
The Need for a Study of soil in its natural condition. *C. F. Shaw.*

13 Le problème de la Terre (Semaine Sociale du Canada, XII Session, Rimouski, 1933).

14 U.S. Department of Agriculture, Yearbook, 1906.
The use of soil surveys. *J. A. Bonsteel.*

15 U.S. Department of Agriculture Yearbook, 1920.
Uses of soil survey. *Charles H. Seaton.*

16 Changing Viewpoints and Methods in Soils Classification. Scientific Agriculture, March, 1926. *A. H. Joel.*

17 University of Montana Agricultural Experiment Station. Preliminary Soil Report, Bull. 158, Sheridan County.

Summary

THE VALUE OF THE SOIL SURVEY. Auguste Scott, Agricultural College, Ste. Anne de la Pocatière, P.Q.

An endeavour has been made to show that an agricultural map would be of great benefit to the Canadian farmers by guiding them in the choice of a locality and supplying them with disinterested and exact information as to the value of the soil and the crops that may be grown there. It would also enlighten those who desire to improve their cropping systems, and enable them to benefit by the experience of other farmers having soils of the same type, in other parts of the country. Soil classification has such a wide scope that the whole nation would benefit by it. From a national point of view it would be very beneficial by supplying a complete inventory of the country; as regards settlement, by concentrating the settlers' efforts on land which is really fit for cropping; and as regards agriculture, by providing for a better adaptation of the crops to the various types of soils. These advantages would also have a practical application. To support this claim, I need only recall the investigation conducted by Dr. Auguste Pépin, in November, 1921, when he asked the New York State agronomists, by circular letter, what they thought of soil survey. The answers which he received were almost unanimous in praising the advantages of this work.

Is this work sufficiently advanced in our country, to produce all the advantages which we have claimed for it? This can hardly be answered in the affirmative, at least in so far as Quebec, the Maritimes and certain Western provinces are concerned. In conclusion, may I express the hope that the Soils Group of the C.S.T.A., shall bring to completion, as soon as possible the agricultural map on which work was started last year.

A STATEMENT ON THE REPORT OF RESEARCH AND EXPERIMENTAL PROJECTS IN SOILS UNDER WAY IN CANADA[1]

This report, as compiled to June 1, 1934, lists over 100 separate projects which have been officially reported as being under way in Canada at the present time. The number of projects alone does not convey a true conception of the nature and amount of the work being done on soil problems. Because of the broad scope of research and experimental work in the investigation of soil problems ranging from fundamental studies of the soil itself through the whole field of soil-plant relationships in crop production, it is obviously difficult to make more than a very broad classification of these projects at this time. To indicate something of the field of investigation covered in the projects reported, they may be grouped roughly, as follows:

Soil Survey—10 projects

Soil Chemistry—16 projects

Soil Fertility—Field experiments and correlated laboratory investigations—49 projects

Soil Cultivation—5 projects

Soil Microbiology—5 projects.

In analyzing the information contained in the project outlines, only a general statement concerning the nature and scope of the work in each of the above fields, is possible at this time.

Soil Survey, Soil Classification and Soil Mapping are reported as being conducted as definite projects in British Columbia, Saskatchewan, Manitoba and Ontario, the type of survey (reconnaissance or detailed), field procedure, the scheme of classification, etc., varying according to the requirements of each Province. Soil Surveys in connection with other investigations are also being carried on in Alberta and Quebec. New Brunswick, Nova Scotia and Prince Edward Island have not been reported as having definite soil survey or soil mapping projects under way.

The survey projects under way in some cases, involve correlative laboratory studies of the soil types in relation to both soil formation and fertility problems.

The projects classified under soil chemistry include extensive investigations on the nature of phosphorus and potassium compounds in soils; solubility studies of phosphorus and potassium compounds; vertical distribution of the readily soluble phosphorus and potassium in the profiles in relation to soil type; studies on fixation of phosphorus and potassium; nitrate production in soils under different treatment; reaction in relation to soil type; investigation of extraction and analytical procedures with soils, etc. Most of this work is fundamental in nature and the principles

[1] A preliminary statement on the work of the Soils Group of the C S T A. in compiling a Report of Research and Experimental Projects in Soils Under Way in Canada. This report has been completed and will be available for distribution in mimeograph form in April, 1935. The preliminary statement was prepared by Prof. G. N. Ruhnke, Ontario Agricultural College, Guelph, and presented to the Soils Group of the C.S.T.A. at the annual meeting at Macdonald College, June, 1934.

established are being applied to the study of problems of soil classification, plant nutrition and fertilization.

As the report shows, the largest number of projects falls into the group designated as soil fertility projects. In practically all of the Provinces, this phase of soil work is receiving most attention. Field plot experiments with a great variety of crops, single and combination fertilizer treatments, rotations, methods of application and rates of application of commercial fertilizers and manure, and greenhouse pot experiments are being carried out in connection with fertility problems. The most extensive work on field experiments is reported by the Field Husbandry Division of the Central Experimental Farm, although some provincial institutions have very extensive programmes of field fertility investigations.

Several of these projects involve physical, chemical and bacteriological laboratory investigations. No doubt the urgent demand for information relating to the most effective use of commercial fertilizers in crop production has resulted in the great emphasis placed on this phase of soil work.

Projects on methods of cultivation are also reported by the Field Husbandry Division of the Central Experimental Farm, Ottawa. In the case of the various provinces, projects of this type have not been organized to any great extent.

Projects in soil micro-biology are reported from British Columbia, Manitoba, Alberta and Quebec. Some of this work is strictly fundamental in character and some of it is being done in connection with other research and experimental projects in soil fertility. The reports received would indicate that this phase of soil investigation has not received extensive attention generally throughout the provinces.

The present status of soil work in Canada, as gleaned from the reports of projects sent in from the various provinces and from the Central Experimental Farm at Ottawa may be briefly summarized as follows. By far the largest number of research and experimental projects with soils fall in the field of soil fertility investigations. In practically all provinces, this phase of the work has received, and is continuing to receive, most emphasis and attention. Projects in soil chemistry are next in order of number of projects, whether in fundamental studies or in connection with soil survey and soil fertility investigations. Soil survey projects are next in order of number and are extensively developed in a number of the provinces. In some provinces, no soil survey work has been reported as being under way.

Actually, a very large amount of work in soil investigation is being done at the present time, although the amount of laboratory investigation of a fundamental nature is much less than the amount of work being done in a field experimental way. There is a trend toward the development of more extensive fundamental laboratory investigations which are desirable if the most successful experimental work is to be carried out in the field and applied through the extension service. It would appear that there is opportunity for considerable development in the field of fundamental investigations in all the provinces. There is real need for such investigational work in connection with the organic and inorganic constituents of soils, the nature of the complexes involved, and the nature and solubility of soil compounds. Further, there is need for the correlation of such studies with soil formation processes and studies in soil genesis and morphology.

It is natural to expect that the economic demand for information relating to land utilization and fertilization for crop production will, for a long time, require that experimental work along the soil fertility lines be given first attention. Nevertheless, it must be emphasized that the fundamental investigations necessary for the establishment of principles to be applied in soil fertility work should receive more attention than they have in the past. It is quite apparent too, that soil survey and soil classification projects are of vital importance as a basis for the organization of other systematic soil studies, whether in the laboratory or in the field. It may be said, however, that the soil investigational work now under way, as reported in the project outlines, is all necessary and important work and is, apparently, organized along the very best lines in each of the various provinces. There is an urgent need for more general recognition of the importance of soil investigations to the end that further support may be available to expand this work. This is particularly true in the case of those provinces where the work has not developed as rapidly as would be desirable.

It is realized that this general analysis of the Report must be considered only as tentative, and made without adequate time to study fully the whole field, and in the light only of the limited information contained in the project outlines.

ANNUAL MEETING OF THE SOILS GROUP OF THE C.S.T.A.

The annual meeting of the Soils Group of the C.S.T.A. was held at Macdonald College, P.Q., June 26 and 27, 1934. The programme was prepared by the officers of the Group for 1933-34 who were: Dr. E. S. Hopkins, Central Experimental Farm, Chairman; Dr. A. Leahey, University of Alberta, vice-chairman; and Dr. R. R. McKibbin, Macdonald College, Secretary. The papers and main committee reports have been assembled for this issue of Scientific Agriculture under the direction of Dr. McKibbin and Dr. Hopkins. The following officers were elected for the year 1934-35: —

Chairman—Dr. A. Leahey, University of Alberta, Edmonton, Alta.
1st Vice-Chairman—Dr. R. R. McKibbin, Macdonald College, P.Q.
2nd Vice-Chairman—Prof. August Scott, Ecole Superieure d'Agriculture, Ste. Anne de la Pocatière, P.Q.
Secretary—Dr. J. Mitchell, University of Saskatchewan, Saskatoon, Sask.

REPORT ON THE PREPARATION OF A SOIL ZONE MAP OF CANADA[1]

At the Soils Group meeting of the C.S.T.A. held in June, 1932, it was decided that the preparation of a genetic soil map of Canada should be undertaken. To this end Professor A. H. Joel of the University of Saskatchewan was appointed to undertake this work, with the aid and co-operation of a committee composed of a representative from each province. As chairman of this committee Professor Joel devoted considerable time and energy to the project, so that, in the ensuing year, excellent progress was made. At the next annual meeting the chairman reported that the committee members had submitted such provincial soil zone maps as were available, and that from these he had plotted a preliminary composite map. During the discussion of this work in committee it was decided that this preliminary composite map should be submitted to each member so that each could make a copy and thus become familiar with the information at present available.

In April, 1934, Professor Joel resigned from his position with the University of Saskatchewan, on account of ill health, and much to the regret of all the members of the Genetic Soil Map Committee, he was unable to continue the work he was doing so ably as their chairman. The writer was appointed to carry on the chairmanship of this committee in his stead.

At the next Soil Group meeting held at Macdonald College in 1934 the committee members present met and reviewed the work which had been done to date. In some of the provinces, larger areas have been covered by soil survey, and some workers have been able to do the work in more detail. Consequently there are a number of gaps which require to be filled in the general map and these require further work on the part of the individual members of the committee before the publication of a completed map is justified.

The project involves the zoning of over three and a third billion acres. It is a task of considerable magnitude, and to bring the project to completion requires the continued activity and co-operation of each committee member so that the details of each province may be available as the field work progresses.

The present chairman is compiling further information of a general character which will be sent to the various committee members for criticism and correction when the necessary compilations and sketch maps are finished.

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[1] Statement presented by Prof J. H. Ellis of the University of Manitoba to the Soils Group of the C.S.T.A at the annual meeting at Macdonald College, P.Q. June, 1934.

A NEW TYPE OF BEE COUNTER

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A common method of measuring the activity of bees is to count the number that enter or leave a hive during the period under investigation. Several devices have been used to obtain this count, one of the most recent being that of the photo-electric cell, whereby the bee is made to pass through a narrow channel and interrupt a beam of light to a photo-electric cell, thereby breaking the photo-electric current. By a suitable relay this can be registered on a counter. One channel, however, is not sufficient to obtain an accurate count of the bees that enter or leave the hive. The introduction of a sufficient number of channels with photo-electric cells for each would make the expense almost prohibitive. To overcome this difficulty a photographic method was substituted for the photo-electric.

The method is simply to photograph a small spot of light on a moving photographic film so as to have a fine line traced on the film; suitable arrangements are made whereby a bee in passing through a channel interrupts this light thus making a break in the line. The number of breaks in a given time gives the number of bees that pass through the channel. As many channels as may be desired can be photographed on the same film.

The arrangement of the apparatus is shown in Plate I, and diagrammatically in Figure 1.

Figure 1 gives a diagrammatic representation for a single channel. Light from a 250 watt bulb passes through the cylindrical lens (G) and an opening (Q) at the top of the channel, and is brought to focus on a thin white paper (R) placed above the narrow slit (S). The white paper is thus strongly illuminated and a wide angle photographic lens (T) focuses this spot of light on the moving film (Y). The moving film is mounted as in a motion picture camera and travels at the rate of 8 inches per minute by means of a motor with a suitable reduction gear. The bee crossing the slit makes a distinct break in the trace. The driving wheel (L) and the guiding wheel (J) with the two spools (M) and (N) were obtained from a movie camera while the guide pins (K) are placed there so that the position

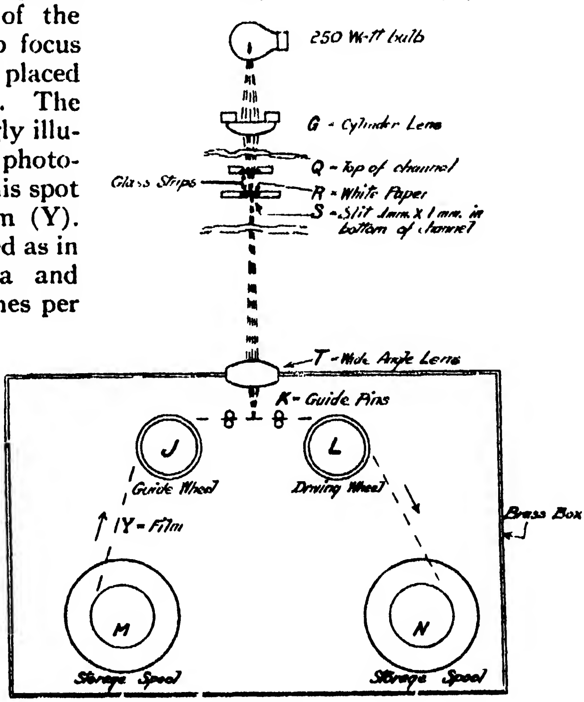

FIGURE 1

[1] Director.

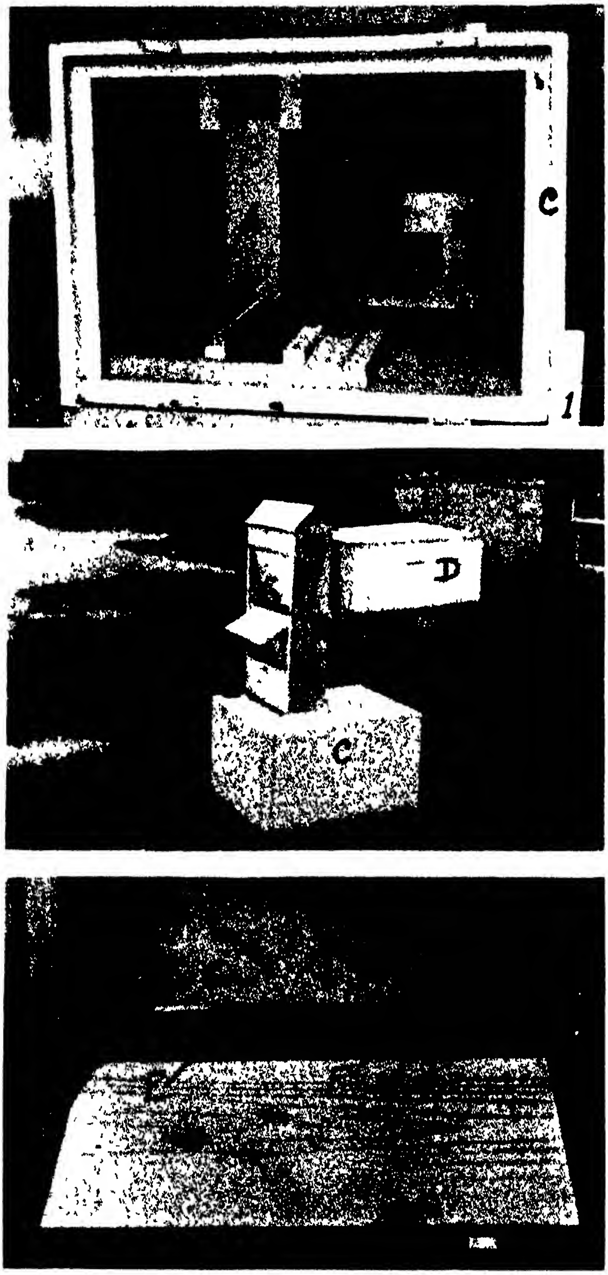

PLATE I

1. Motor driven camera in box. 2. Hive and counter complete. 3. Entrance tunnels.

A. Camera B. Motor. C. Camera box. D. Hive. E. Entrance tunnels. F. Gate on tunnel. G. Focussing lens. H. Lamp housing.

of the film will not be changed with reference to the focus. The film winds off spool (M) on which there is a slight tension in order to prevent the film unrolling of itself, and is stored on the spool (N). This spool is turned by a friction belt drive which is not shown.

The apparatus as actually used is shown in Plate I. (A) is the camera box, made of brass and light tight. It is so arranged that it can be easily removed, and by means of stops it is always put back into exactly the same position. The mounting of the reduction gear for the motor is shown in (B), the motor being behind the plate. A worm gear with a suitable reduction drives the small pulley shown in (B) This pulley by means of a belt drives the pulley shown above (B). This latter is connected directly to the driving wheel (L), Figure 1. By suitably arranging the reduction gear and the relative diameters of the pulleys any desired movement of the film per minute can be obtained.

A front view of the channels is shown at (E) (Plate I, Figure 3). In this particular case, there are 24 channels so arranged that the bees can leave through 12 of them and enter the hive through the alternate 12. This was arranged by means of small trap doors The ends of the tunnels were bevelled at an angle of 45°, and a thin piece of celluloid suspended from a fine wire hinge to cover the opening. These gates could be opened only by a bee entering the tunnel from the other end. As the odd numbered tunnels had the gates on the outer end, and the even numbered ones on the inner end, they were thus made one-way passages, half being exits and half entrances.

The cylindrical lens (G) above the channel focuses the light on the thin sheet of white paper below the channel as explained in Figure 1. It was found that white paper gave the best results. To omit the paper the light was not so intense nor of so good a colour for photographic purposes. Oiling the paper did not improve it. The paper was held in position by means of a thin glass strip placed above it.

The complete mounting of hive and apparatus is shown in Plate I, Figure 2: (D) is the hive; (C) the box containing the camera and motor; (E) the channels by which the bees could enter or leave the hive, and (H) a housing for the lamps.

A positive motion picture film 35 mm. wide was used. This was very considerably cheaper than a negative film, but it required two 250-watt lamps to illuminate the white paper. This caused considerable heat, so that it was necessary to protect the hive by means of an asbestos sheet. The film travelled at the rate of 8 inches per minute and time signals were put on every five minutes by turning off the light for ten seconds. It was found that a special mark had to be put on one end of the film so as to know which end was exposed first.

By counting by eye the number of breaks in each line it is possible to obtain the total number of bees passing in or out in a given time. This counting could also be done by projecting the film on to a screen and thus enabling the count to be made more easily. This is possibly the most tedious part of the method, but it has one advantage in that it gives a permanent record which is always available for study.

This apparatus was designed in consultation with Dean W. H. Brittain of Macdonald College, for use in his studies on the activity of bees.

INHERITANCE OF SEED COLOR IN ALFALFA[1]

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The extent to which normal well matured alfalfa seed may vary in color is not generally recognized. Close examination of a bulk sample or, better still, the seed from a population of individual plants, will show that while the dominant color is a bright greenish yellow, the density of color extends through a range of from very light yellow to orange or light brown. Of interest in this connection are certain exceptional plants which produced true black and true white seed. When the former were crossed with yellow seeded plants they gave F_1 hybrids which produced seeds of various shades of mulatto. It seemed worth while to investigate as far as possible the inheritance of the black and white seeded characters and to determine whether it might be feasible to use the former as a marker for identifying improved strains.

REVIEW OF LITERATURE

The literature dealing with seed color studies in general is not very extensive and this is especially true with reference to leguminous plants. Without attempting to cover all of the original papers, a brief review will be made of the more important inheritance studies relating to seed color in legumes.

The comparatively recent work on inheritance in soybeans by Woodworth, Owen, Stewart, and other investigators has been summarized by Woodworth (*5*). The efforts of these workers have shown that in the seed color inheritance of soybeans many factors are involved. The most important of these constitutes two multiple allelomorphic series, one conditioning the expression of black and brown pigments in the seed coat and the other series acting as inhibiting factors.

Hallquist (*1*) postulates the following genetical formulae for *Lupinus angustifolium:*—R, a basic factor for pure red flower color and rust brown seed color, the double recessive having white flowers and white seeds. B, a factor which, together with R, gives bluish red flowers and earth brown seeds. In the presence of R, a factor V transforms the pure red color into violet. V does not influence the seed color.

In *Vicia Faba*, Sirks (*4*) found that seed color depends primarily on a factor O. In the absence of O, whitish gray seeds are produced which are converted by Y into yellow white. O with P gives yellow, and with p purple seeds. Another factor Sc in the presence of O produces black seeds, and a factor M, causing mottling of seeds, is linked with O.

In the case of alfalfa, no studies on the inheritance of seed pigmentation seem to have been reported.

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[1] Contribution from the Division of Forage Plants. A thesis presented to the Faculty of Graduate Studies and Research of McGill University in partial fulfillment of the requirements for the degree of Master of Science.

MATERIAL AND METHODS

Black Seeded Parent and Progeny

The black seeded plant was discovered in a third generation selfed line of Grimm alfalfa. It was a good seed producer and appeared to be well developed although somewhat reduced in vigor, but not more so than other plants in the same progeny. Both selfed seed and open fertilized seed were obtained from this original black plant. It is believed that the other plants in the same line were yellow seeded but definite information is lacking on this point.

In the next generation, 20 L_4 plants were produced from selfed seed and 20 plants also from open-fertilized seed taken from the original parent. The former were dwarf, being greatly reduced in vigor and the seed of all was either black or dark mulatto, except one which produced yellow seed. The progeny from open fertilized seed on the other hand was composed of plants so exceptionally vigorous that no doubt existed as to their hybrid origin. It was definitely known that the female parent was black seeded, while the male parents were presumed to be yellow, an altogether likely assumption. The seed produced by these plants exhibited various shades of mulatto but none of them were as black as the original parent or as light in color as the average for common alfalfa. All of the seed from each plant was remarkably uniform in color. The material available to the author at the beginning of this study consisted of selfed seed from 19 F_1 plants, 11 of the L_4 plants and open fertilized seed from the white seeded plant.

One of the most serious difficulties encountered in this study was the almost complete self-sterility of the L_4 black seeded plants. Self-sterility was a characteristic of all plants in this selfed line, and it was more or less evident in some of the hybrid progeny when black seeded individuals were used as the female parent. Lack of fertility was evidently associated with loss of vigor due to inbreeding and there were indications that it may have been linked with factors which are responsible for pigment in the seed.

A study of the floral parts of these L_4 plants did not reveal anything out of the ordinary except a marked constriction of the pistil in the central region. Examination of numerous flowers of common alfalfa failed to disclose a similar constriction. It is not probable that this peculiarity affected fertilization, since F_1 seed was obtained with the L_4 plants as female parents, indicating that the ovules were functional. An examination of pollen from plants of this line showed that there was a considerable percentage of sub-normal grains and that the starch content of functional grains was less than normal, yet the amount of good pollen seemed ample to effect fertilization. Furthermore, the successful germination of these pollen grains on an artificial medium and the fact that pollen from the L_4 plants was effective in fertilizing emasculated flowers of ordinary plants, indicates that a considerable proportion of the pollen was viable.

The root-tips of these plants were examined cytologically and in all cases the normal number of chromosomes ($2n = 32$) were observed, nor was there any evidence of chromosome abnormalities.

Since, as has been shown, the L_4 plants produced pollen grains and ovules which were functional and since there was no evidence of chromosome aberrations, it is evident that a case of self-incompatability obtains

in this line. It is also evident that whatever is the immediate cause of this self-incompatability, it may be regarded as one of the effects of continuous inbreeding.

Figure 1 shows the various lots of breeding material which were grown and studied. It will be observed that seed was secured from Black × Yellow, Black × White, and White × Yellow hybrids. This, in addition to the F_2 families resulting from natural hybrids between the original Black parent and normal yellow seeded plants, provided the most important data which were obtained on the inheritance of seed color.

Most of the studies which have been made on inheritance have presented a problem in classification and the present one was no exception. It was soon apparent that we were dealing with a wide range of color variability due on the one hand to blending inheritance and on the other to pronounced differences in shades of color as a result of environmental conditions.

In view of the various shades of mulatto exhibited by F_1 natural crosses from near yellow to dark mulatto, and in view of the wide range of variability due to segregation in the F_2 families produced from them (See Table 2), and furthermore the various differences in shades of color observed in a good sample of ordinary alfalfa seed, it was decided that a consistent analysis of the breeding material could be secured only by setting up an arbitrary scale of color values. Accordingly, seed samples were selected which could be used as type samples covering the entire range of color from light yellow on the one hand to dense black on the other. This resulted in a number of samples which were placed in series in as many compartments under transparent celluloid. The greatest degree of difference between any two adjacent samples was only sufficient to be recognized.

The procedure in classifying the individual plants consisted in placing the seed samples harvested from them in a sliding compartment by means of which it could be moved back and forth along the series of type samples until it was properly matched and its classification determined. It then received a number corresponding to the number of the type sample. Altogether 18 type samples were obtained, these being assigned numbers from 1 to 18, indicating the range in color from very light yellow to black.

Very light yellow seed samples occurred quite frequently which appeared to be at least one distinct shade lighter in color than a bright, well matured sample of ordinary alfalfa. The so-called black seed was not a coal black but rather what might be described more correctly as a deep purplish black. The casual observer, however, would designate the color as black. The pigment was definitely located in the seed coat. Between yellow and black, as previously stated, were various shades of mulatto which graded into each other insensibly; that is to say, there were no distinct lines of demarcation which could be recognized.

To insure accuracy of classification all seed samples were examined twice by daylight and then under an electric fixture, which provided a uniform source of illumination. Finally all samples having the same color number were examined together and compared with one another. Any samples deviating significantly from the type sample of the group were reconsidered with respect to classification. When samples were available from the same plant representing seed produced by it in more than one

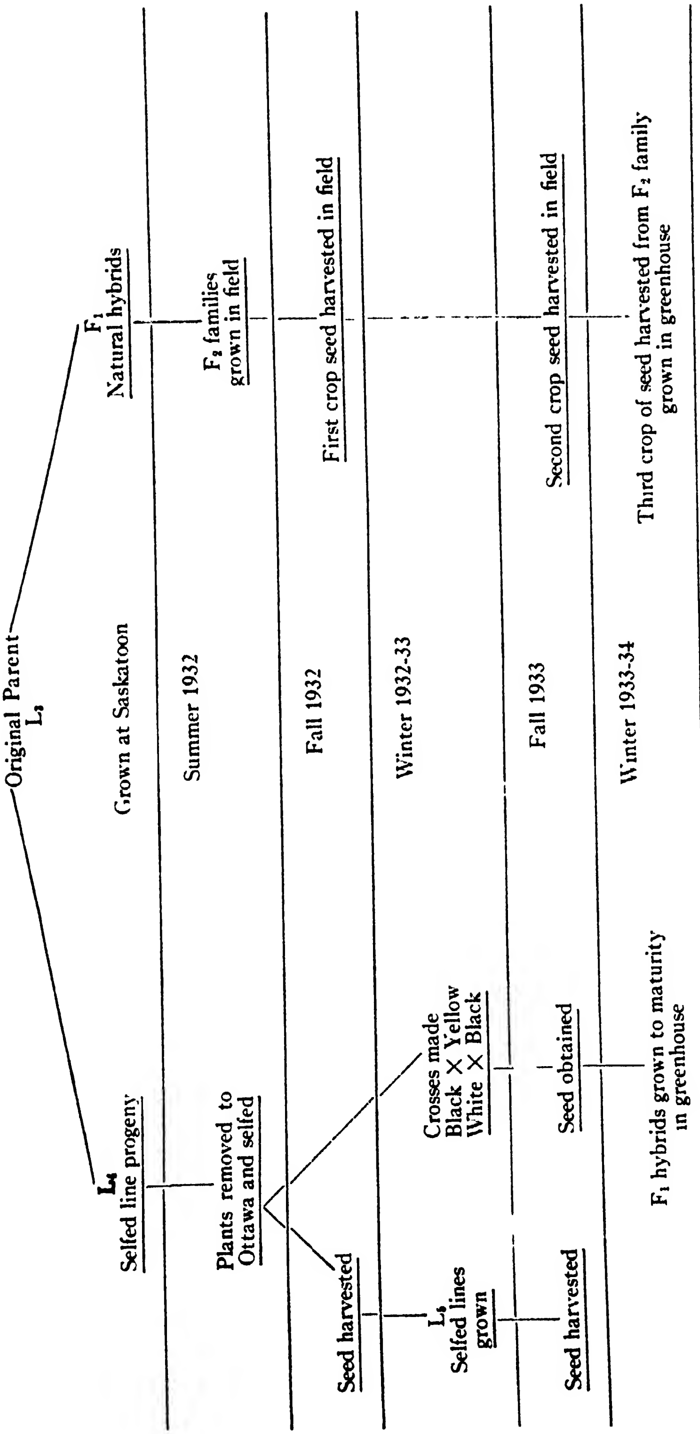

FIGURE 1. Outline of experimental procedure showing the main lines of descent in the inheritance study of seed color in alfalfa.

season or in the greenhouse, the darkest color was considered to be closest to the correct classification for that particular plant.

The lack of color differences sufficiently definite to form distinct color classes was the chief justification for establishing as large a series of color types as possible. It was recognized that these color classes should not be expected to correspond to as many phenotypes but it was thought that many rather than few sub-divisions of the color range would make for greater accuracy of classification. This was undoubtedly the case. Moreover, the procedure which was adopted permitted of any system of grouping found to be most appropriate in the light of the data as a whole.

In the first place, consideration had to be given to the degree of variability in color and its probable cause as between seed on individual plants matured in a single season, as between plants grown in the same season, and also as between the same plants grown in different seasons or in the greenhouse.

Seed color of F_1 natural hybrids in 1931 exhibited wide differences as between plants, a fact that will merit further discussion, but examination of these showed remarkable uniformity within each sample. These plants matured under ideal weather conditions in Western Canada. Uniformity was less striking in single plant samples harvested at Ottawa in 1932 and 1933. There remained the question, therefore, as to whether or not the density of color might not be influenced to some extent by weather conditions which preceded maturity of the seed. There was also the possibility that seed color might become intensified between the time that the pods first appeared to be ripe and the time that the seed was harvested. This is a matter of some importance since pods taken from plants in the field will not all have matured at the same time. An attempt was made to settle this point by growing a number of plants in the greenhouse under controlled temperature and illumination. Each pod was labelled when it first appeared to be ripe and seed samples having the same date labels were harvested thereafter at intervals of two or three days. Comparison of these samples of seed demonstrated that the color had reached its full expression when the pods had turned brown and that it did not change materially after that time. Seed produced on single plants in the field, however, matures over a considerable period of time during which atmospheric conditions may be anything but uniform. There is the probability therefore that atmospheric conditions in the field may be responsible for more or less variability in seed color produced by individual plants matured at different dates in the same season.

It was equally difficult to determine the degree to which color intensity may vary as between plants of the same genetic constitution grown in the same season, for the reason that environmental effects on seed color could not be divorced from genetic effects. It would seem that the influence of climatic conditions in these cases should not be much greater than in the case of seed from pods taken from the same plants at different times as they reach maturity. What evidence there was indicated that such effects were not very marked but probably sufficient to increase very materially the difficulty of making an accurate genetic classification of the material.

The greatest degree of variation in color was found to occur between seed samples taken from the same plants in different seasons. Seed was

harvested in both 1932 and 1933 from the same plants and in the case of one large F_2 family they were then taken from the field and propagated in pots in the greenhouse with artificial illumination during the winter of 1933-1934. The seed produced under all three environmental conditions by each plant was then classified according to the arbitrary scale of color values and each was assigned the number corresponding to the type sample which it resembled most closely. Of 102 plants tested in this way, the seed samples from 18 plants were classified under a single color type, 47 under two, 25 under three, while 12 plants varied in color by as many as four shades in the color series.

White Seeded Parent and Progeny

The white seeded plant was found in the alfalfa breeding nursery at the University of Saskatchewan. It was one among many plants of the Grimm variety which were being harvested individually for seed. This plant had white flowers and the seed was wholly lacking in yellow pigment. Lack of color in both flowers and seeds indicated that in all probability the plant was homozygous recessive with respect to pigmentation. Open-fertilized seed was secured but the plant itself has not been available for this study.

In the spring of 1932, a progeny of 80 seedlings were grown in the greenhouse at Ottawa from this white alfalfa seed. These were transplanted into the field early in the spring. The plants flowered and produced seed the first season. Among these were found two white flowered and white seeded plants. It was assumed that these came from selfed seed and that the remaining 78 plants represented F_1 hybrids, the result of natural crossing between the original white seeded plant and normal yellow seeded individuals. All of the plants with colored flowers produced yellow seed, a fact which argues for the theory that the original parent was a double recessive.

In the fall of the year the two white-flowered and white seeded plants grown at Ottawa in 1932 were transplanted into pots and removed from the field into the greenhouse. One of these (W.S.1) proved to be completely male sterile. Examination of the pollen showed that it was non-functional. The other plant (W.S. 2) gave a few selfed seeds from which eight plants were obtained, all of which produced colorless flowers and seeds, a further indication of the homozygous recessive character of the colorless condition.

Although W.S.1 was male sterile it produced seed readily when fertilized with the pollen from other plants, and because it was unnecessary to emasculate the flowers, this plant was used, rather than W.S.2, in most of the crosses with yellow seeded and black seeded plants as male parents.

In 1932 a large number of the plants were selfed which had been grown from open-fertilized seed taken from the original white seeded parent. It was assumed, with considerable justification, that those which had produced colored flowers and seeds were White × Yellow natural F_1 hybrids. In the spring of 1933 about 900 seedlings comprising 10 L_2 families were transplanted into the breeding nursery. Under normal conditions this material would have flowered and produced some seed the first season, thus providing definite information on the genetics of the white seeded character. Unfortunately this alfalfa nursery was severely attacked by

leaf hoppers. Although the plants were saved by repeated treatments with insecticide, the growth was retarded to such an extent that the plants failed to set seed and a large proportion of them failed to bloom. Of those which blossomed a considerable number had white flowers but it was impossible to secure reliable ratios.

Breeding Behaviour:

Figure 2 shows the results obtained in two successive generations from selfing the parent plant. Figures in brackets indicate the color type. In the first generation from selfed seed (L_4) 20 plants were obtained of which 11 produced seed. Ten of these varied in color from 14 to 18 and one produced yellow seed. This is evidence for the heterozygous character of the parent.

Repeated attempts were made to obtain selfed seed from the L_4 plants both in the field and in the greenhouse. In all, approximately 8,000 flowers were tripped artificially. Seed was obtained from only four plants and the resulting progenies contained a total of only 47 individuals. The color classification of seed produced by the L_5 plants in relation to the L_4 progeny and the original parent is shown in Table 1.

TABLE 1.—CLASSIFICATION OF THE ORIGINAL L_3 BLACK SEEDED PARENT AND THE FOURTH AND FIFTH GENERATION SELFED LINES, ACCORDING TO TYPE SAMPLES

Designation of plants	Seed color classes																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
L_3																		1	1
L_4				1										2	3	1	2	2	11
L_5 (B2)		2																	2
L_5 (B8)						2		1	1		3	1	1			1			10
L_5 (B12)					2	3	7				1								13
L_5 (B13)					2	5	3	3		2	3	3	1						22

With reference to Table 1 it is worthy of note that selfed seed was easily obtained from the original L_3 parent while the L_4 plants were almost or completely self-sterile. The difference in this respect can be accounted for by the fact that the L_3 plant was reasonably vigorous and well developed, whereas all of the L_4 plants were much reduced in size and decidedly lacking in vigor of growth. Kirk (2) has shown that inbreeding has a very pronounced effect on seed production, so much so that the majority of selfed lines produce very little seed in the fourth generation and many of them are completely sterile. He has shown also that pronounced loss of vigor may take place in any generation. In this case it occurred in the fourth.

In view of the high degree of self-sterility exhibited by the L_4 plants, it seems altogether probable that the 47 plants reported in L_5 may have resulted from accidental fertilization with foreign pollen. Their position in the color series (see Table 1) strongly suggests that they are F_1 Black × Yellow hybrids rather than fifth generation selfed lines. This number of accidental hybrids from some 8,000 flowers which were tripped might

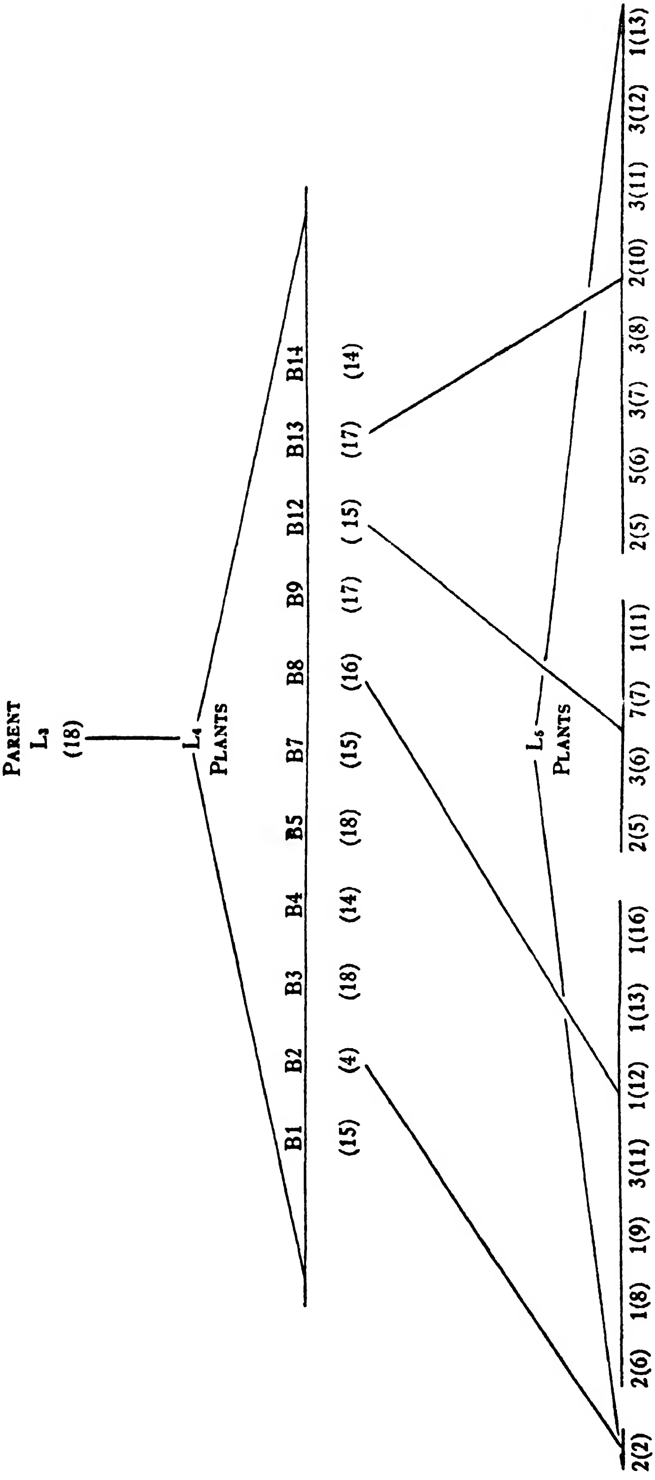

FIGURE 2. Distribution with respect to seed color of fourth and fifth generation inbred progenies from the original black seeded parent plant. (Seed color classes in brackets.)

occur even with the best of technique. At any rate it is safer to disregard these plants when considering the data.

One other feature of Table 1 that is of interest, is the occurrence of the single yellow seeded plant classified under 4. There is little doubt that this individual properly belongs in the L_4 selfed line since it was dwarf and otherwise similar to the other plants in appearance. As will be seen, it is not so difficult to account for this plant as for the absence of individuals in the color series from 5 to 13 inclusive. The smallness of the population, however, must be taken into consideration.

Table 2 shows the distribution of F_2 plants in relation to the color series. These families are the progenies of F_1 hybrids obtained from crosses between the original black seeded parent and normal yellow seeded plants. It is important to note that the male parents are not necessarily the same for any two families.

TABLE 2.—CLASSIFICATION OF F_2 FAMILIES, ACCORDING TO TYPE SAMPLES

F_2 families	Seed color classes																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1		1		2	2	1	2		4	4	**4**	2							22
2	1	8		13	7	**6**	6	9	12	3	4	1							70
3		1		4	**13**	15	12	9	16		1								71
4			1			1	**2**		2	2									8
5	2	1	1	16	6	1	12	3	11	4									57
6				3		3	**2**	7	8	4		1							28
7	16	4	3	12	9	22	27	**5**	43	47	17	5	4	2					216
8	4		1	6		3	4	3	**23**	16	5	3							68
9	1			2		10	8	12	**15**	11	3	5	1			1			69
10			1	4	1	1	3	3	3	2	3	**8**	6	3	2	2	3	4	49
11				1	1	1	2	1	1	1	4	**2**	1	3	1				19
12	10	2		7	6	4	19	**8**	20	6	2	2	2		1				89
13	4	1			1	7	8	4	10	**8**	8	7	7	5	2	2		3	77
14	5	2	1	2	2	4	12	3	**12**	11	3	2	2						61
15	3		4	19	12	25	47	17	127	**117**	61	49	13	2	1	1			498
16	1		1	5	2	9	**16**	5	9	5	2	1							56
17			2	2	1	**14**	30	3	4	2	1								59
18				1	2	3	5		3	2	4		1		1				22
19	5	1			2	16	17	**4**	10	4	1	1							61
																			1,598

NOTE.—Heavy figures indicate the color classification of the F_1 parent of each family.

Heavy figures indicate the color classification of the F_1 parent of each family. The F_1 hybrids obviously must have been essentially different with respect to genetic constitution in order to account for the pronounced dissimilarity of F_2 progenies in the distribution of individuals. These peculiarities of family behaviour in breeding must be attributed to the heterozygosity of the female parent, and probably also to differences in the genetic constitution of the male parents.

An interesting and very significant feature of Table 2 is the deficiency of black and dark mulatto seeded plants. Only two families produced black seed and only 24 plants out of approximately 1,600 are classified in the four darkest groups. Even in the color range above 12, at which point there appeared to be a transition from medium to dark mulatto,

there are only 77 plants. This fact strongly suggests that most of the plants in the range of darkest seed color have been eliminated by a factor or combination of factors which produce gametic or zygotic lethal effects.

Table 3 shows the distribution of F_1 hybrid plants with respect to seed color from Black × Yellow crosses. The first horizontal row contains the F_1 hybrids obtained by fertilizing the original black seeded plant with pollen from yellow seeded parents, while B_1, B_2 - - - B_{14} are the L_4 plants shown in Table 1. As might be expected, many of the hybrids are located in the intermediate color classes from 9 to 12 inclusive, indicating that there is a blending of color inheritance, but on the other hand it is difficult to account for the disproportionate numbers which are classified as 5, since this color class corresponds closely to what may be regarded as normal yellow. The distribution resulting from L_8 Black × Yellow F_1 plants approaches much more closely to what might be expected from Mendelian segregation than does that of any of the L_4 Black × Yellow hybrid groups.

TABLE 3.—CLASSIFICATION OF F_1 HYBRIDS FROM BLACK × YELLOW CROSSES ACCORDING TO TYPE SAMPLES

Crosses	Seed color classes																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
L_4 B1 × Y					1	3	3	3	4	2	1	2							19
L_4 B1 × Y				4		5	1	4	3	1	4	1							23
L_4 B2 × Y		1			12	6													19
L_4 B4 × Y					3	1	2		1										7
L_4 B5 × Y					3	2	2		3										10
L_4 B8 × Y					6	3		3	7										19
L_4 B9 × Y					1			4	10	2	4								21
L_4 B12 × Y					18		2		4		2	3							29
L_4 B13 × Y					3		3	1	2		10	3	1	1					24
L_4 B14 × Y								1	2		1	3							7

Table 4 gives the distribution of F_1 hybrids from crosses between the white seeded plants previously referred to (W.S.1 and W.S.2) and the same black seeded L_4 plants which were used as female parents in Black × Yellow crosses (see Table 3). The crosses listed in Table 4, however, had the white seeded plants as female parents. Reciprocal crosses were not possible since the latter were male sterile.

The distribution of F_1 individuals in Table 4 is similar to that in Table 3, except that in the former a large group of plants occur in the color series under 1 and 2, whereas they are wholly absent in Table 3. These color types correspond to a very light shade of yellow which is not commonly found in a well matured sample of alfalfa. Since there is little doubt that the female parents were homozygous recessives with respect to pigmented seeds, it is reasonable to assume that those plants which fall in groups 1 and 2 are heterozygous for the factor or factors which condition the normal yellow seed color. The sharp distinction between light yellow, corresponding to types 1 and 2 in the color range, and typical yellow corresponding to types 4 and 5 is very conspicuous.

In Table 4, as in Table 3, the complete absence of black and the darker shades of mulatto in the color series from 13 to 18 inclusive, as well as the decided tendency toward skewed distributions toward the yellow end of the series, are considerations worthy of note. It would appear also that in Table 4 the largest frequencies from White × Black crosses occur in color types 9, 10 and 11, while those in Table 3 from Black × Yellow crosses are found under color number 5, which is yellow.

There is one other observation in Table 4 that baffles explanation on any theory of Mendelian inheritance. This is the fact that W.S.$_1$ × B$_2$ gave two F$_1$ hybrids which were classified under 11 in the color series. B$_2$ is the yellow seeded L$_4$ segregate from the original black seeded plant and W.S.1 lacks both the black and yellow pigment. It is difficult to understand how this union could possibly result in offspring with mulatto colored seed coats. It is instructive to compare the distribution of F$_1$ plants from this cross with that of the B$_2$ × Yellow cross in Table 3, since the same L$_4$ yellow seeded segregate was used in both. In the latter case no plants were found which would classify above 6 in the color series.

TABLE 4.—CLASSIFICATION OF F$_1$ HYBRIDS FROM WHITE × BLACK CROSSES ACCORDING TO TYPE SAMPLES

Crosses	Seed color classes																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
WS1 × L$_4$B$_2$	12	1				2	1				2								18
WS1 × L$_4$B$_4$	7	3			1		3		1	6	6								27
WS1 × L$_4$B$_6$					1	2		2		1	4								10
WS1 × L$_4$B$_8$	1	3			4			3	9	1									21
WS2 × L$_4$B$_8$	3			2	1		1		4										11
WS1 × L$_4$B$_9$	7	2		2	3	1		3	4	16	13	3							54
WS1 × L$_4$B$_{12}$	8	3		3	4	1	6	2	4	5	10	4							50
WS1 × L$_4$B$_{18}$	2				1	1	3	1	3	7	4								22
WS2 × L$_4$B$_{13}$					3						2								5

Discussion of Results

There are two ways in which the original black seeded plant may have originated. Black-seededness may have appeared as a result of repeated selfing since it was found in a third generation selfed line; or it may have arisen as a mutation in the parent plant one generation before. Under the first assumption it is necessary to postulate that the black color was carried along in the heterozygous condition and that it found expression only when the factors which conditioned this character had reached homozygosity. It is apparent from the data that the original plant did not breed true for the character in question.

If black-seededness appeared as the result of mutation it is unlikely that the mutation occurred at more than one locus. It is reasonable to expect, therefore, that the plant would be heterozygous for the factor responsible for this character. This was found to be the case, which argues for the theory of origin by mutation. It presupposes that black-seededness was due primarily to a single factor difference.

It is obvious from the distribution of plants in F_2 families that if a monofactorial mutation was responsible for the appearance of black or dark purple pigmentation in the seed of the original parent plant, this change in the genetic constitution does not provide an adequate explanation of the type of segregation which was obtained. The distribution of individuals is such as to suggest a fairly complex type of inheritance requiring the assumption of two or more modifying factors to account for the variability in seed color. Thus at least three genetic factors would be involved, and quite possibly more, in the inheritance of black-seededness. In addition there is certainly at least one factor for yellow in the homozygous condition which is responsible for the yellow pigments of normal alfalfa seed. The absence of this factor or factors results in white seed.

According to this analysis of seed color inheritance the factorial constitution of the original black seeded parent may be written YY C_1c_1 C_2c_2 Bb where the genes are represented by Y for yellow pigment, B for black pigment, and C_1 C_2 for factors which modify the expression of the black color. It is necessary to assume heterozygosity for the three factors responsible for black and mulatto because the presence of factors in the homozygous condition would not alter the picture. The number of modifying factors, however, could be postulated as three instead of two with equal justification.

It is not possible with the available data to arrive at a genetic formula which is entirely acceptable. The single factor mutation for black seems to be a logical assumption. It is not unreasonable to expect that modifying factors should affect the expression of this character. A seed sample of ordinary alfalfa exhibits a wide range of color variation which in all probability has a genetic basis. In most of the seed color studies with leguminous plants, modifying factors have been found to play a prominent part. On the other hand, while the three factor hypothesis fits the facts reasonably well there are certain features of the data which are difficult to harmonize. Some of these are doubtless due to variation as the result of environmental effects which influence the physiology of the plant. Assuming, however, that the genes are complementary and their effects cumulative, the suggested genetic complex provides a fairly satisfactory hypothesis as a possible explanation. The most serious discrepancies in the data are the deficiency of black and dark mulatto seeded plants in F_2 families and the occurrence and breeding behaviour of the yellow seeded L_4 segregate previously mentioned. The deficiencies can only be accounted for by assuming that these plants have been eliminated by gametic or zygotic lethals.

There is considerable evidence to indicate that pigmentation of the seed coat may be profoundly influenced by physiological factors.

An interesting case in point is that of seed-coat mottling in soybeans which has been studied superficially by many workers. Enough has been done to show that plant physiology assumes the major role in this phenomenon. Inheritance undoubtedly plays a part but most yellow or green seeded varieties are subject to mottling under certain environmental conditions. Heredity is undoubtedly the ultimate controlling factor, but mottling is apparently inhibited except under those peculiar conditions which make the expression of this character possible.

Owen (*3*) discusses this question rather fully and refers to the work of Onslow who found, among other things, that some species formed starch and others did not. To quote: "The interesting point in this connection is the high negative correlation that was found between starch and pigment formation. In species that were not able to synthesize starch, sugars accumulated; and since sugars are used in the formation of anthocyanins, a logical reason can be given for pigmentation. Plants that were able to form starch, she assumes, made use of their sugars in that process, and the quantity of sugar left was insufficient for the production of pigments." Since the black and brown pigments which are primarily responsible for mottling were found to be glucosides, an explanation of their production by means of an accumulation of sugars has been proposed by Owen. He found the most striking evidence for this theory in his observations that mottling was greatly increased by reviving the growth of plants after the seeds were practically mature. Also it was found that mottling varied on different parts of the same plant.

In the case of pigmentation of seed in alfalfa there is no doubt as to the dominant part played by hereditary factors. At the same time there is reason to believe that physiological factors influenced the development of pigment to a greater or less extent. If this were the case, a satisfactory explanation of the data on breeding behaviour would become extremely difficult. At the same time it would provide a partial answer for some of the discrepancies which were found in an attempt to compare the results with genetic expectations.

If, for instance, we accept Owen's (*3*) suggestion and assume that the original black seeded parent plant not only carried a factor for black-seededness but also that it lacked the normal power of synthesizing starch, its behaviour in breeding would depend as much on the type of inheritance exhibited by the latter as by the former. Assuming segregation in both cases to be regular, normal Mendelian ratios would still be expected, the factor or factors for "starch formation" simply acting as color determiners or modifiers. But if the inability to form starch was also conditioned by vigor of growth, as appears to be the case with seed production, then the least vigorous plants would tend to have pigmented seed provided they also possessed the necessary inheritance. Conversely, the most vigorous plants would tend to produce seed with the minimum amount of pigment. The segregation obtained in F_2 would then be influenced by the degree of heterozygosity of individual plants in each family as well as by the random assortment of factors which condition seed coat color. This hypothesis could be used quite effectively to explain the distributions obtained in F_2 families, the marked deficiency of dark seeded plants in Table 2 and the unexpected types of F_1 plants secured from the W.S.1 $\times$ L_4, B2 crosses in Table 4. It would also help to explain why such a large proportion of the F_1 plants in Tables 3 and 4 occur at the yellow end of the color series.

Once it is established that physiological causes are operative in modifying the expression of a character, the difficulty of a satisfactory solution to the problem is greatly increased and the opportunities for speculation are numerous. Most of the seed color studies with leguminous plants have run into this difficulty and the present study is no exception in this respect.

One of the objectives in this investigation was to determine whether it might be possible to utilize seed coat pigmentation in alfalfa as a character for identifying an improved strain. Such a distinguishing feature might some time prove very useful because of the fact that varieties of alfalfa are so similar in appearance. Its utilization for this purpose, however, could be practical only if the character were inherited in a simple manner and preferably as a double recessive. Inheritance in this case has been shown to be fairly complex with the further probability that physiological factors affect the expression of the character. Furthermore it was not possible to secure fertile homozygous black seeded plants because of self-incompatability which characterized all of the inbred plants in this line. It was concluded therefore that the character in question was valueless from a utility standpoint.

Summary

1. This paper presents the results of an investigation to determine the inheritance of black and white seed coat characters in alfalfa and whether or not the former could be utilized in breeding as a marker for identifying improved strains.

2. The black seeded plant was discovered in a third generation selfed line of Grimm alfalfa and the white seeded plant occurred in a population of Grimm alfalfa plants which had not been inbred.

3. The fourth generation selfed line from the original black seeded parent consisted of 20 plants all of which, except one which had yellow seeds, produced either black or very dark mulatto seeds. A similar number of F_1 natural hybrids, between normal yellow seeded male parents and the original black seeded plant, produced seed which varied in color from light to dark mulatto. The results obtained from numerous Black × Yellow and White × Black crosses were reported.

4. Each of 19 F_2 families of the Black × Yellow cross exhibited a wide range of variability with respect to seed coat color extending from yellow on the one hand to fairly dark mulatto on the other. With the exception of two families there was a marked deficiency of plants in the very dark color classes.

5. The available evidence indicated that the white seeded parent was homozygous for a recessive factor which results in the absence of yellow pigment, and that the inheritance of this character was comparatively simple. Inheritance of the black seeded character, on the other hand, was fairly complex, requiring the assumption of at least three factor pairs. The original black seeded plant was thought to have arisen as a single gene mutation. This gene, primarily responsible for pigmentation of the seed coat, together with at least two modifying factors were postulated as the most probable genetic factorial basis to account for the breeding behaviour of the original black seeded parent.

6. The data strongly suggest that the expression of seed coat color was influenced to some extent by physiological factors which were conditioned by the environment.

7. It was concluded that the character of black-seededness would be valueless from a utility standpoint.

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Literature Cited

1. HALLQUIST, C. The inheritance of the flower color and the seed color in *Lupinus angustifolium*. Hereditas, *2* : 299-363. 1931.
2. KIRK, L. E. The progeny test and methods of breeding appropriate to certain species of crop plants. Amer. Nat., *67* : 515-531. 1933
3. OWEN, F. V. Hereditary and environmental factors that produce mottling in soybeans. Jour. Agr. Res., *34* : 559-589. 1927.
4. SIRKS, M. J. Contributions to a genetic analysis of the horse bean, *(Vicia Faba)*. Exp. Sta. Rec., *68* : 176-178. 1933.
5. WOODWORTH, C. M. Genetics of the soybean. Jour. Amer. Soc. Agron., *25* : 36-51. 1933.

ETUDE COMPARATIVE DE QUELQUES FROMAGES RENFERMANT LE PENICILLIUM GLAUCUM[1]

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INTRODUCTION

Il existe sur le marché canadien quelques fromages d'importation, très analogues au point de vue de leurs propriétés organoleptiques; tels sont: le Grove City américain, le Stilton anglais, le Roquefort français et le Gorgonzola italien. En effet, ces divers fromages possèdent en commun les caractères suivants: ils sont à pâte fermentée et ferme; ils contiennent des marbrures verdâtres; ils développent une odeur rance et une saveur "poivrée" caractéristique.

Les marbrures sont produites par les ramifications d'un champignon microscopique, le "*Penicillium glaucum*" dont on ensemence le caillé avant la mise en moule et ultérieurement le fromage, lorsqu'on désire favoriser son persillage et activer sa maturation.

L'odeur et la saveur caractéristiques du Roquefort et des fromages similaires avaient été d'abord attribués aux spores et aux filaments fructifères du champignon. Le principe chimique de l'arôme était apparemment le butyrate d'éthyle. Mais l'expérience démontra d'une part, que le *Penicillium glaucum* cultivé sur milieu artificiel ne produisait rien de la saveur particulière du Roquefort, même en plein stade de sporulation, et que d'autre part, le fromage ne renfermait pas de butyrate d'éthyle. Il fallait donc rechercher la cause ailleurs. Currie (*2*) qui fit une étude spéciale sur le sujet, arriva aux conclusions suivantes:

"(1) During the ripening of Roquefort cheese a considerable amount of the fat is hydrolysed;

(2) *Penicillium roqueforti* (*glaucum*) produces a water-soluble lipase, which is the chief factor in the accomplishment of the hydrolysis;

(3) The hydrolysis results in the accumulation of the acids of milk fat in both the free and combined forms;

(4) Of these acids, caproic, caprylic, and capric and their readily hydrolyzable salts have a peppery taste and are responsible for the characteristic burning effect of Roquefort cheese upon the tongue and palate."

En conséquence de ce qui précède, les fromages analogues au Roquefort et contenant le *Penicillium glaucum* doivent fournir à l'exemple de ce dernier, des acides volatils en proportion comparativement plus forte ou plus faible selon que leur goût est plus ou moins accentué. D'autre part, si ces acides libres ou combinés sous la forme de sels minéraux, sont réellement libérés des glycérides par un processus hydrolytique, on doit observer simultanément une augmentation de l'acidité totale et une élévation de l'indice d'iode de la matière grasse. Car, contrairement au rancissement par auto-oxydation (à la suite d'une période d'induction plus ou moins

[1] Préliminaire d'une étude entreprise en coopération par le Département de l'Industrie Laitière de Washington, D.C., et l'Institut Rosell de Bactériologie Laitière, Inc., Oka, P.Q.

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longue), le rancissement par hydrolyse épargne les liaisons éthyléniques. La faculté d'absorption de l'iode n'étant pas amoindrie, l'indice de celui-ci qui est relatif à un poids constant de matière grasse, doit nécessairement subir une augmentation.

Le présent travail dont les résultats préliminaires apparaissent ci-après, a été entrepris dans le but de vérifier les conclusions relatives au Roquefort ainsi que les considérations théoriques qui viennent d'être faites au sujet du Grove City, du Stilton et du Gorgonzola. Comme cette étude est envisagée d'un point de vue comparatif, il était nécessaire de déterminer d'abord la composition et le rapport de maturation des spécimens d'expérience, afin d'être en mesure d'effectuer les comparaisons sur une base uniforme de référence.

METHODES D'EXPERIMENTATION SUIVIES

Détermination des principaux constituants:

L'échantillonage et les déterminations de l'humidité et des cendres ont été effectués selon les méthodes officielles de l'A.O.A.C. (pages 238 et 239 (*1*).

Pour obtenir les protéines totales, on dosait l'azote d'après la méthode Kjeldahl-Gunning sur des prises d'essai de 2 grs et on utilisait le facteur de conversion 6.38.

Pour doser la matière grasse on s'est servi de l'appareil Soxhlet à épuisement continu. Le fromage était broyé au mortier avec du sable calciné et soumis à une extraction à l'éther de 14 heures. L'extrait gras était évaporé, desséché à poids constant à 100° C et pesé. Les déterminations portaient sur des prises d'essai de 5 grs. L'extrait gras était ensuite conservé dans l'exicateur à $CaCl_2$ pour servir aux essais ultérieurs.

A titre comparatif, deux déterminations de gras furent également faites d'après la méthode Babcock, utilisant à cet effet des échantillons de 9 grs et des éprouvettes à crème de 18 grs. Les résultats obtenus par cette méthode furent sensiblement les mêmes; étant inférieurs de 0.1 à 0.2%.

Les principaux constituants, c.à.d.: eau, protéines totales, matières grasses, cendres, ont été déterminés en duplicata, sur des échantillons bien représentatifs, et d'une manière identique dans tous les cas.

Tableau 1—Composition centésimale

	Eau	Protéines	Graisses	Cendres
Grove City	37 53	21 50	31 25	6 0
Roquefort	36 90	21 33	31 20	6 9
Gorgonzola	38 15	23.33	30.81	5.5
Stilton	35.43	23.51	31 50	4 2

Les résultats rapportés à 100 grs de fromage sont compulsés dans le Tableau 1.

Détermination de l'acidité.—Le pH a été apprécié par colorimétrie à l'aide d'un indicateur LaMotte et de bromothymol-bleu; ce dernier servait à préciser les chiffres de la région supérieure à pH 6.

L'acidité totale a été déterminée par la méthode officielle de l'A.O.A.C. (page 239 (*1*)).

Les chiffres de l'acidité ionique et de l'acidité totale figurent au Tableau 2.

TABLEAU 2—ACIDITÉ

	pH	cc. N/10 NaOH pour 100 grs.
Grove City	4 0 ± 0 1	184
Roquefort	4 5 ± 0 1	146
Gorgonzola	6.0	108
Stilton	6 2	105

Détermination des acides gras volatils.—Les acides gras volatils totaux et libres ont été dosés d'après la méthode de F. Edelstein et E. Welde, modifiée par McCanchey (*6*). On appliquait la méthode de la manière suivante: 20 grs de fromage étaient broyés avec 250 cc. d'alcool à 96°. On chauffait le mélange jusqu'à ébullition dans un matras muni d'un régrigérateur ascendant. On jetait sur un filtre et on lavait le résidu avec de l'alcool bouillant. Le filtrat était divisé en deux parties égales et chacune d'elles était traitée avec une solution étendue de NaOH jusqu'à réaction légèrement alcaline, puis évaporée à siccité sur le bain-marie à 60° C. Le résidu saponifié était repris par l'eau, additionné de 10 cc. H_3PO_4, gr. sp. 1.12, puis distillé à la vapeur sous pression réduite pendant 2¼ heures. On s'assurait de la bonne marche de la distillation à l'aide du réactif au molybdate d'ammonium. Une portion aliquote du distillat était titrée avec N/10 NaOH en présence de phénolphtaléine.

Pour obtenir la fraction des acides gras volatils libres, on distillait par le même procédé, une suspension aqueuse de fromage non additionnée de H_3PO_4. On titrait comme précédemment. La différence entre les deux résultats correspond aux acides gras volatils combinés, c.à.d., neutralisés par NH_3 et les bases mobilisées au cours de la fermentation du fromage.

Les résultats exprimés en grammes d'acide butyrique par 100 grs de fromage sont réunis dans le Tableau 3.

TABLEAU 3—ACIDES GRAS VOLATILS ET ACIDE LACTIQUE POUR 100 GRAMMES

	Ac. gras vol. totaux	Ac gras vol libres	Ac. gras vol. combinés	Ac. lactique
Grove City	1.3060	0 8448	0 4612	0 034
Roquefort	0 4279	0 1084	0 3195	0
Gorgonzola	0 3450	0	0 3450	0
Stilton	0 3437	0	0 3437	0
	en acide butyrique			

Détermination de l'acide lactique.—L'acide lactique a été déterminé par la méthode proposée par P. Léone et B. Tafuri (*4*). Cette méthode est basée sur l'oxydation de l'acide lactique à l'état d'acétaldéhyde et sur la conversion de cette dernière en oxime.

On procédait de la façon suivante: l'acide lactique étant très soluble dans l'eau, on faisait une macération de 20 grs de fromage dans 150 cc. d'eau. On jetait sur un filtre et l'extrait aqueux était utilisé pour la recherche et le dosage. Pour la recherche, on employait 10 à 20 gouttes d'extrait et 10 cc. de réactif d'Uffelmann; eau phéniquée à 4%, perchlorure

de fer officinal, 1 goutte (5). Tous les fromages ont donné une réaction négative ou non-concluante. Malgré cela, l'on a quand même procédé à la détermination quantitative en ayant soin d'employer une solution très étendue d'hydroxylamine.

L'extrait aqueux contenant l'acide lactique était introduit dans un appareil type Kjeldahl avec 100 cc. H_2SO_4 à 50% et on distillait pendant une heure à 140-150° C. Le distillat était recueilli sur une solution N/100 d'hydroxylamine dans laquelle NH_2OH avait été mise en liberté au moyen d'une solution de NaOH d'un titre correspondant à une réaction exactement neutre à la phénolphtaléine:

$$NH_2.OH.HCl + NaOH = NH_2.OH + NaCl + H_2O$$

Pendant la distillation on faisait passer dans l'appareil un faible courant d'air, utilisant pour cela la trompe à eau. On obtenait ainsi l'oxime:

$$NH_2OH + CH_3CHO = CH_3.CH{:}N.OH + H_2O$$

L'excès de NH_2OH était ensuite titré avec N/100 H_2SO_4 en présence de méthyl orange. La différence entre ce résultat et celui obtenu par un essai à blanc correspond à NH_2OH combinée, et par conséquent à l'acide lactique.

L'expérience a été conduite avec beaucoup de précaution. Chaque type de fromage a fait l'objet de deux ou de trois déterminations et les résultats furent concordants, toujours négatifs pour le Roquefort, le Gorgonzola et le Stilton, tandis que le Grove City a fourni 0.033 et 0.035 gr. d'acide lactique par 100 grs de fromage.

J'ai néanmoins l'intention de reprendre le dosage de l'acide lactique en suivant concurremment la méthode ci-dessus décrite qui date de 1931, les méthodes de T. F. Friedmann, M. Coronio et P. A. Shaffer (1927) et de A. Meyer (1933).

Détermination de l'ammoniac.—Le dosage de NH_3 a été effectué de la manière habituelle. Des macérations de fromage à 10% étaient décantées sur filtre. Une partie du filtrat était saturée par MgO, puis soumise à la distillation. L'autre partie était distillée telle quelle. Dans les deux cas, on recueillait le distillat dans N/10 H_2SO_4 et on titrait l'excès d'acide avec N/10 NaOH en présence d'hélianthine. On obtenait ainsi NH_3 total et NH_3 libre, respectivement. La différence entre les deux résultats donnait l'ammoniac des sels ammoniacaux. Le Tableau 4, groupe les résultats exprimés en gramme pour 100 grs de fromage. Ce tableau comprend aussi le rapport ammoniacal, lequel augmente avec le degré de maturation.

Tableau 4—Ammoniac total et libre (pour 100 grammes)

	NH_3 total	NH_3 libre	NH_3 combiné	Rap. ammoniacal
Grove City	0 365	0 187	0 178	1.050
Roquefort	0 348	0.178	0.170	1 047
Gorgonzola	0 512	0 322	0 190	1 694
Stilton	0 302	0 170	0 132	1 287

Détermination de l'absorption de l'iode et de la chaleur de bromination.—L'extrait éthéré ayant servi à la détermination du gras, et maintenu à l'exicateur, était utilisé pour la mesure de l'indice d'iode et de la chaleur de bromination. L'indice d'iode était déterminé de la façon habituelle, sur des prises d'essai de 0.4 à 0.55 gr.

On mesurait la chaleur de bromination sur des prises de 1 gr. d'extrait gras, en suivant la méthode de Gill et Hatch (*3*). On employait à cet effet, 5 cc. de $CHCl_3$ et 5 cc. de la solution chloroformée de brome.

Les indices d'iode calculés en partant de la chaleur de bromination (facteur de conversion 5 5 de Helner et Mitchell) sont légèrement plus faibles que ceux obtenus directement par la méthode de Hübl. Les résultats comparatifs figurent au Tableau 5.

TABLEAU 5—INDICE D'IODE ET CHALEUR DE BROMINATION

	Extrait gras sec, en gr.	Sol. N/10 $Na^2S^2O^3$ (fact. 0 905)	Indice d'iode trouvé	Chaleur de bromination	Indice d'iode calculé (coef. 5 5)
Grove City	0 500	20 2	46 41	8 2	45 10
Roquefort	0 505	23 0	52 33	9 0	49 50
Gorgonzola	0 420	17 2	47 05	8 5	46 75
Stilton	0 544	21 1	44 56	7 9	43 45

Détermination de la chaleur de bromination.—(Nouvelle technique applicable au fromage).

La méthode de Gill et Hatch préconisée pour l'examen des huiles et des beurres, donne des résultats constants et concordants lorsqu'on l'applique à l'extrait gras des fromages. Mais, comme l'extraction de la matière grasse est une opération de longue durée (12 à 14 heures), j'ai songé à établir une technique qui permettrait d'opérer directement sur le fromage. J'ai obtenu de bons résultats en procédant de la manière suivante. On pèse exactement une quantité de fromage correspondant à un gr. de matière grasse. On triture minutieusement ce fromage dans un mortier avec deux volumes de sable fin, calciné. On dépose le mélange sur le fond d'un tube à essai de 50 cc. On lave le mortier avec 15 cc. de $CHCl_3$ ou de CCl_4 ajoutés en deux fois. On introduit le liquide de lavage dans le tube sans toucher les parois de celui-ci. On mélange intimement avec une baguette de verre et on laisse reposer dans le colorimètre pendant 2 minutes. On ferme le tube à essai avec un bouchon muni d'un thermomètre très sensible, fixé de façon à ce que le bulbe plonge dans la solution qui surmonte le sable. On note la température au dixième près. On introduit alors 5 cc. de la solution habituelle de Br (4 volumes $CHCl_3$ ou CCl_4 + 1 volume Br) qu'on laisse couler sur les parois du tube. On bouche immédiatement et on mélange par quelques mouvements de rotation. On note exactement le maximum de température au dixième près. La différence entre les deux lectures, multipliée par 2, donne la chaleur de bromination, et cette dernière multipliée par le coefficient habituel 5.5, fournit l'indice d'iode.

Bien que le nombre des essais soit encore très restreint, je me suis permis d'exposer ici cette technique tout en demandant aux lecteurs de bien vouloir considérer la présente note comme une communication préliminaire, entendu qu'il faudra encore vérifier les résultats obtenus par des expériences faites sur un plus grand nombre de fromages. Le Tableau 6 résume les résultats obtenus et permet de faire les comparaisons nécessaires.

TABLEAU 6—CHALEUR DE BROMINATION DÉTERMINÉE DIRECTEMENT SUR LE FROMAGE

	Pour cent de matière grasse	Poids de fromage en gr.	Température obtenue	Chaleur de bromination	Indice d'iode calculé	Indice d'iode trouvé
Grove City	31 25	3 200	4 2	8 4	46 2	46 41
Roquefort	31 20	3 205	4 9	9 8	53 9	52.33
Gorgonzola	30 81	3 245	4 3	8 6	47 3	47.05
Stilton	31 50	3 174	4.0	8 0	44 0	44 56

RESUME ET CONCLUSION

Une étude comparative de quelques fromages renfermant le *Penicillium glaucum* a été faite au point de vue (1) de la composition: eau-graisses-protéines-cendres; (2) de la teneur en acides gras volatils; (3) de l'indice d'iode et de la chaleur de bromination.

La recherche de l'indice d'iode et de la chaleur de bromination a fourni l'occasion d'élaborer une nouvelle technique qui permet d'opérer directement sur le fromage.

De l'ensemble des résultats obtenus, on peut tirer les principales conclusions suivantes.

1o—Le Grove City, le Stilton, le Roquefort et le Gorgonzola accusent sous le rapport des constituants bruts, une composition très voisine. Cependant le Roquefort se signale par une teneur notablement plus élevée en matières minérales. Ceci doit être attribué à deux faits: (a) le lait de brebis est plus riche en cendres que le lait de vache; (b) le Roquefort reçoit plus de NaCl au salage.

2o—Il existe une parallélisme frappant entre la teneur en acides gras volatils et l'intensité de la saveur. Au point de vue de l'intensité décroissante de cette dernière, les fromages étudiés se classent dans l'ordre: Grove City, Roquefort, Gorgonzola et Stilton. Considérés au point de vue des proportions décroissantes d'acides gras volatils totaux, ils conservent le même ordre. Ceci confirme la conclusion de James N. Currie "les acides caproique, caprylique, caprique et leurs sels facilement hydrolysables sont la cause de la saveur caractéristique du Roquefort" et permet d'étendre cette conclusion aux fromages Grove City, Gorgonzola et Stilton.

3.—Les acides gras volatils sont évidemment le résultat d'un processus hydrolytique, car aux chiffres élevés de l'acidité totale et de l'acidité ionique (par rapport au lait dépourvu d'acide lactique) correspondent des indices d'iode de la matière grasse, également élevés. L'augmentation comparativement plus grande de l'indice d'iode dans le cas du Rcquefort est un fait normal, puisque les glycérides du lait de brebis contiennent plus d'acides à liaisons éthyléniques que ceux du lait de vache.

4.—Les chaleurs de bromination obtenues par la technique nouvelle donnent des indices d'iode concordants. En outre, ceux-ci se rapprochent davantage des chiffres trouvés par la méthode de Hübl, que ceux calculés d'après la chaleur de bromination de l'extrait éthéré des fromages.

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BIBLIOGRAPHIE

1. Association of Official Agricultural Chemists. Official and Tentative methodes of analysis. Washington. 1930.
2. Currie, James N. Flavor of Roquefort Cheese. U.S. Dept. Agr. Bull. A-5 : 13. 1914.
3. Leach, Albert E. Food Inspection and Analysis, 4th edition. John Wiley, New-York. 1920.
4. Léone, P. et Tafuri, B. Détermination quantitative de l'acide lactique. Le Lait, II : 748. 1931.
5. Maheu, J. Recherche qualitative de l'acide lactique. Le Lait, 2 : 436. 1922
6. McCanchey. Deutsches Archiv. fur physiol. Chemie, 72 : 140. 1917.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

Wholesale prices in Canada remained unchanged in November and December, 1934, the index being 71.2. One of the features of price conditions during the past year was the relative stability of wholesale prices. The index in January was 70.6 but rose to 72.3 in August and declined again to 71.2 in November. The index of wholesale prices of Canadian farm products rose from 55.3 in January to 61.6 in December; this represented a gain of more than 6 points.

Retail Prices.—The index number of retail prices was 78 2 in January and rose to 79.9 in March, after which it declined until June, when it again stood at 78.2. This was followed by a rise until November when it reached 79 4; the December index was 79.0. The index number of prices of foods was highest in March when it was 72 9 but fell to a low point of 67 6 in June from which it rose to 69 9 in November and receded to 69.3 in December.

Physical Volume of Business.—As this is being written, data for the physical volume of business in the month of December are not available. Comparison must, therefore, be made on the basis of the first eleven months of 1934. The index was at the low point of 86 8 in January, rose to 99 0 in August and declined to 95 5 in October. The November index was 96 5. Industrial production followed a somewhat similar course; the low point of 83 9 was registered in January. It rose to 99 9 in May, fell off again in June and July but was 99 8 in August; the November index was 97 0.

Mineral production has been substantially above the monthly average for 1926 throughout the eleven month period, reaching a high point of 160 2 in April. Similarly, in manufacturing, the low point was 86 2 in January, and in two of the succeeding months, May and August, this index rose above the monthly average for 1926. The figure for November was 96 0 as compared with 94 8 in October. Newsprint output has been at high levels during 1934. Production of iron and steel showed some improvement. Automobile output was much above that in 1933. Construction continued to improve but progress is not rapid. Agricultural marketings showed wide fluctuations being largely influenced by the movement of grains. The index of cold storage holdings was above that a year ago.

Agricultural Products.—Wholesale prices of Canadian farm products advanced from 55 3 in January to 61 6 in December. The index of prices of field products rose from 47 9 in January to 60 7 in August, declined to 55 3 in October and rose to 56 0 in December. Prices of animal products have been at somewhat higher levels. The low point was reached in August but there were substantial gains in September and October while prices were maintained in November and showed a slight gain in December. The general level of wholesale prices of Canadian farm products in 1934 averaged about 15% above that in 1933, but compared with the low point of the depression prices in December had advanced about 43%.

The index of agricultural marketings was 51 2 in November compared with 61 2 in the previous month, being largely influenced by grain marketings which declined from 57 9 in October to 46.2 in November, slower movement of wheat being largely responsible. There was a slight advance in the shipment of oats but marketings of other grains were quite low.

Hog marketings were higher in November than in October but there was a smaller movement of other live stock, particularly sheep and lambs. According to the live stock market report, 52,622 head of cattle were exported to Great Britain during 1934 compared with 53,006 in 1933. Domestic sales of cattle at public yards totalled 696,549 head in 1934 as against 602,537 in the previous year. Sales of calves were

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1933									
Jan.	63.9	43.6	35.1	57.9	79.1	68.1	62.2	56.1	112.0
Feb.	63.6	43.0	36.0	54.7	78.4	67.0	60.0	76.5	127.6
Mar	64.4	44.7	38.0	56.0	77.8	68.4	62.5	129.0	135.8
April	65.4	46.8	41.1	56.4	78.0	69.8	65.1	104.1	112.7
May	66.9	51.2	46.9	58.4	77.0	76.4	72.7	95.4	110.4
June	67.6	52.6	49.4	57.9	77.0	82.2	79.8	221.9	119.9
July	70.5	60.1	60.8	59.0	77.2	84.1	82.6	221.9	119.9
Aug.	69.4	57.0	54.9	60.5	78.6	89.8	89.5	197.2	114.2
Sept.	68.9	54.7	49.5	63.4	78.5	90.8	90.2	101.1	115.7
Oct.	67.9	51.4	44.6	62.8	77.9	88.2	87.4	70.5	112.7
Nov.	68.7	53.8	46.7	65.8	78.1	85.5	83.9	41.8	111.1
Dec.	69.0	53.3	45.3	66.6	78.4	86.2	85.1	30.7	107.6
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.8
Nov	71.2	61.2	55.7	70.4	79.4	96.5	97.0	51.2	130.4
Dec.	71.2	61.6	56.0	70.9	79.0	92.4	91.0	36.0	135.7

1. See Prices and Price Indexes 1913-1928, pp 19-21, 270 289 and 1913 1932, p 15

2. Wholesale prices of Canadian products of farm origin only See Prices and Price Indexes 1913-1932, p 32, and Monthly Mimeographs 1933 and 1934.

3 Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products

5. Including foods, rents, fuel, clothing and sundries. See Prices and price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.

Prices and Price Indexes 1913-1931, p 122, and Monthly Mimeographs 1933-1934.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

369,661 and 316,901 respectively. Sheep marketed numbered 458,608 during the past year compared with 471,217 in 1933. Hog gradings were 3,014,198 head in 1934 as against 3,170,582 graded in 1933.

Prices in United States.—Indexes of prices paid to farmers for farm products in United States (av. 1910–1914 = 100) in November as compared with October were as follows: grains 109, unchanged; cotton and cotton seed 107, unchanged; fruits 94, as compared with 98; truck crops 105, as against 100; chickens and eggs 125 and 108 respectively; meat animals 72 and 74; the total index was unchanged at 102. The ratio of prices paid to prices received remained at 81. The index of prices paid to farmers in United States was 77 in January; it rose to 84 in March but declined to 82 in May and June. It rose to 103 in September and was unchanged at 102 in October and November.

Prices in Great Britain.—Prices of agricultural produce in Great Britain (av. 1910–13 = 100) have shown improvement over 1933. During the past year, the low point was reached in March when the index was 108. It rose to 119 in August. It was unchanged in September and declined to 115 in October but in each of the first 10 months of 1934 the index was higher than in the corresponding month of 1933.

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE, OTTAWA, PRINCIPALEMENT D'APRÈS LES DONNÉES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

Les prix de gros au Canada n'ont pas changé en novembre et en décembre 1934; l'indice était à 71 2. La stabilité relative des prix de gros a été l'un des faits caractéristiques de la situation l'année dernière. L'indice était à 70 6 en janvier, il s'est élevé à 72.3 en août pour retomber à 71.2 en novembre. L'indice des prix de gros des produits de fermes canadiens est passé de 55 3 en janvier à 61 6 en décembre; ceci représente un gain de plus de 6 points.

Prix de détail.—Le chiffre-indice des prix de détail était à 78 2 en janvier, il s'est élevé à 79 9 en mars, puis il a suivi une courbe descendante jusqu'en juin lorsqu'il s'est remis à 78 2. Il a monté ensuite jusqu'en novembre pour atteindre 79 4; l'indice de décembre était à 79 0 Le chiffre-indice du prix des aliments était à son plus haut point en mars, à 72 9, puis il est retombé au bas point de 67 6 en juin d'où il s'est relevé jusqu'à 69 9 en novembre pour retomber à 69 3 en décembre.

Volume physique des affaires.—Nous n'avons pas, au moment où nous écrivons ces lignes, les données relatives au volume physique des affaires pour le mois de décembre, et la comparaison ne peut donc être faite que sur la base des premiers onze mois de 1934. L'indice était au bas point de 86 8 en janvier, il s'est élevé à 99 0 en août pour retomber à 95 5 en octobre. L'indice de novembre était à 96 5. La production industrielle a suivi une courbe à peu près semblable, le bas point de 83 9 a été enregistré en janvier; l'indice s'est élevé à 99.9 en mai pour retomber à nouveau en juin et en juillet, mais il était à 99 8 en août; l'indice de novembre était à 97.0.

La production minérale a été sensiblement plus élevée que la moyenne mensuelle pour 1926 pendant la période de onze mois, atteignant un haut point de 160 2 en avril. Il en a été de même dans l'industrie manufacturière; le bas point était de 86 2 en janvier et dans deux des mois suivants, mai et août, cet indice s'est élevé au-dessus de la moyenne mensuelle de 1926. L'indice de novembre était à 96.0 contre 94.8 en octobre. La production du papier-journal est restée à un niveau élevé en 1934. La production du fer et de l'acier a fait quelques progrès. Celle des automobiles était bien supérieure au chiffre de 1933. L'industrie du bâtiment a continué à s'améliorer, mais le progrès n'est pas rapide. Les ventes de produits agricoles présentaient de grandes fluctuations; elles étaient surtout influencées par le mouvement des grains. L'indice des stocks conservés au froid était supérieur à celui de l'année dernière.

Produits agricoles.—Les prix de gros des produits de fermes canadiens, qui étaient à 55.3 en janvier, sont montés à 61 6 en décembre. L'indice des prix des produits des champs s'est élevé de 47 9 en janvier à 60 7 en août; il est retombé à 55.3 en octobre pour remonter à 56 0 en décembre. Les prix des produits animaux étaient à un niveau un peu plus élevé. Le bas point a été atteint en août, mais il y a eu une hausse considérable en septembre et en octobre, et les prix se sont maintenus en novembre et légèrement relevés en décembre. En 1934, le niveau général des prix de gros des produits de fermes canadiens était en moyenne d'environ 15% supérieur à celui de 1933, mais il avait monté d'environ 43% par comparaison au bas point de la dépression en décembre.

L'indice des ventes agricoles était à 51 2 en novembre contre 61.2 le mois précédent, en raison de la diminution des ventes de grain, qui, de 57 9 qu'elles étaient en octobre sont tombées à 46 2 en novembre, surtout à cause du ralentissement des expéditions de blé. Il y a eu une légère augmentation dans les expéditions d'avoine mais les ventes des autres grains ont été très faibles.

Il s'est vendu plus de porcs en novembre qu'en octobre, mais par contre les expéditions d'autres bestiaux, et surtout de moutons et d'agneaux, ont été moins considérables. Le rapport du commerce des bestiaux nous apprend qu'il s'est exporté sur la Grande-Bretagne en 1934, 52,622 bovins contre 53,006 en 1933. Les

ventes domestiques de bovins aux marchés publics ont atteint un total de 696,549 têtes en 1934 contre 602,537 l'année précédente. Le nombre des veaux vendus était de 369,661 et de 316,901, respectivement. Les ventes de moutons se chiffraient par 458,608 têtes l'année dernière, contre 471,217 en 1933. Le nombre de porcs classés a été de 3,014,198 têtes en 1934 contre 3,170,582 en 1933.

Prix aux Etats-Unis.—L'indice des prix payés aux cultivateurs des Etats-Unis pour les produits de la ferme (moyenne 1910-1914 : 100) en novembre par comparaison à octobre, était le suivant: —grains 109, aucun changement; coton et graine de coton 107, aucun changement; fruits 94, contre 98; récoltes maraîchères 105, contre 100; poulets et œufs 125 et 108, respectivement; animaux de boucherie 72 et 74; l'indice total qui était à 102 n'accusait aucun changement. Le rapport entre les prix payés et les prix reçus est resté à 81. L'indice des prix payés aux cultivateurs des Etats-Unis était à 77 en janvier, il s'est élevé à 84 en mars mais est retombé à 82 en mai et juin. Il s'est élevé à 103 en septembre et est resté à 102 en octobre et novembre.

Prix en Grande-Bretagne.—Les prix des produits de ferme en Grande-Bretagne (moyenne 1910-13 : 100) se sont améliorés par comparaison à 1933. L'année dernière, le bas point avait été atteint en mars lorsque l'indice était à 108. Il s'est élevé à 119 en août. Il est resté au même point en septembre pour retomber à 115 en octobre, mais dans chacun des dix premiers mois de 1934, l'indice était plus élevé que pour le mois correspondant de 1933.

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FURTHER STUDIES ON THE PARASITISM OF *TAPHRINA DEFORMANS*[1]

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On the Niagara Peninsula, Ontario, peach leaf curl is confined almost exclusively to leaves which develop in the early spring. The absence of leaf curl throughout the summer is interesting inasmuch as new leaves are produced throughout the growing season, and the causal organism, *Taphrina deformans* (Fcl.) Tul., is almost certainly present on peach twigs throughout the year as part of the normal saprophytic micro-flora (*1*). The need therefore of a careful study of the influence of environmental factors on the development of this disease is apparent. The present paper presents the initial results of a study of the effect of temperature and moisture upon the process of penetration and upon the subsequent development of the disease.

The Conditions Requisite for Penetration

A preliminary study of the conditions requisite for penetration was made both with detached shoots collected in the summer and with potted plants forced in the greenhouse during the latter part of the winter. Inoculations were made either by spraying the developing leaves with a spore suspension using an atomizer or by painting the suspension on them with a fine brush. The shoots or plants, as the case might be, were then placed in moist chambers for the duration of the particular experiment. In order to determine whether or not penetration had occurred, the leaves were boiled in lacto-phenol cotton blue until they were cleared and then examined microscopically for infection centres in which the stained mycelium stands out quite conspicuously from the cleared leaf tissue.

The results of a number of such experiments have shown that penetration can occur at temperatures ranging from 50° to 70° F. Within this range mycelium could be found in the leaves 48 hours after the plants were inoculated. Between 45° and 50° F. some penetration did occur but this was distinctly limited. The optimum temperature for penetration probably lies somewhere between 55° and 65° F. but, for reasons which will be apparent later, it is difficult to determine this with any degree of certainty.

The Relation Between Environment and Subsequent Development of Leaf Curl

In this series of experiments potted peach trees which had been inoculated under similar conditions were made to complete the development of their foliage in different environments. As a preliminary experiment eight

[1] Presented at the fourth annual meeting of the Canadian Phytopathological Society, Macdonald College, P.Q., June 26 and 27, 1934.
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FIGURE 1—Four of a group of eleven plants which after the buds had broken were inoculated and incubated for 48 hours at 50° to 65° F. and then transferred for 18 days to a constant temperature chamber at 70° F and 80% relative humidity.

FIGURE 2—As in Figure 1 except that these plants were held at 50° instead of 70° F.

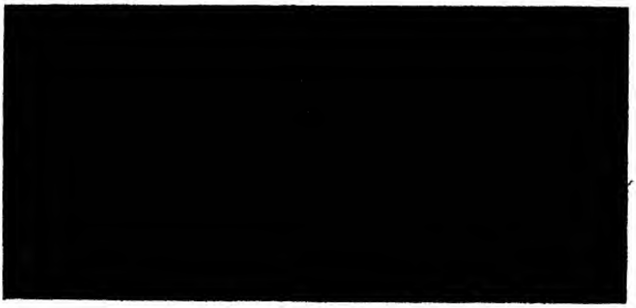

FIGURE 3—Plants of the same lot as in Figure 2 six days later having been held for that time at 60 ° F.

small trees, whose buds were broken so that the first leaves were exposed, were sprayed with a spore suspension of sprout conidia and placed in the inoculating chamber for six days. The temperature of the chamber was held at 45° to 50° F. for the first four days but, as so little penetration occurred during this time, it was decided to raise the temperature to 55° to 60° F. and allow the plants to remain in the chamber for two days longer. When the plants were removed from the chamber they were divided into two lots of four each. One lot was placed in a warm greenhouse (65° to 75° F.) and the other in the coolest house available (45° to 60° F.). At the end of three weeks from the time of their removal from the moist chamber the buds of those plants in the warmer house had developed shoots ranging in length from 6 to 11 inches, but of these only one showed any leaf curl. On the other hand, the buds of the plants in the cooler house had developed more slowly and none of the shoots exceeded six inches in length. On every one of these plants a number of curled leaves developed.

In the next series of experiments temperature and moisture were very closely controlled. The plants were inoculated as before and held in the moist chamber for 48 hours, the temperature varying between a maximum of 65° and a minimum of 50° F. during this period. When they were taken from the moist chamber they were grouped in matched pairs and then divided into two lots each of which contained one of a pair of corresponding individuals. In this way a satisfactory distribution of experimental material was assured. The plants were then placed in two constant temperature chambers, one of which was kept at 70° and the other at 50° F., the relative humidity in each case being 80%. Those in the chamber at 70° F. received 8 hours illumination per day from eight 500-watt tungsten bulbs whereas those at 50° F. received 4 hours per day from a similar source. The effect of this difference in treatment soon manifested itself in the respective rates at which the plants in the two chambers grew. The buds of those in the chamber at 70° F. developed rapidly and within nineteen days produced the foliage shown in Figure 1. On the other hand the plants in the chamber at 50° F. made so little development in the corresponding time (Figure 2) that it was decided to raise the temperature to 60° F. and to increase the illumination to 8 hours per day.

Leaf curl could first be detected on the plants at 70° F. eight days after they were placed in the chamber, but on eleven plants in this chamber only seven curled leaves were developed which were typical and produced asci. A few other leaves on these plants did show indications of being infected during the early stages of their development but they seemed to outgrow the infections as they did not become curled and no asci were produced. On the corresponding eleven plants which were in the 50° F. chamber leaf curl could not be detected until fifteen days after they were placed in the chamber. When the shoots finally did develop every plant showed a heavy incidence of curl and seventeen of the forty-eight shoots were so severely diseased that they developed practically no healthy leaves (Figure 3). The infections on these plants all appeared to be normal ones and in every case asci were produced on the diseased areas when the leaves matured.

DISCUSSION AND CONCLUSIONS

Since penetration of young peach leaves by *T. deformans* occurs readily between 50° and 70° F. and these temperatures are well within our normal summer range, the disappearance of the disease during the summer cannot be due to an inability of the fungus to enter the leaf, but must rather be attributed to factors operating after penetration has taken place. This is further suggested by the fact that the conditions under which the plants grow after penetration has occurred materially influence the amount of leaf curl which develops, those grown at high temperatures developing little or none whereas those grown at lower temperatures become heavily diseased. It seems likely therefor that during the summer new leaves develop so rapidly that their period of susceptibility is passed through before the fungus can establish adequate parasitic relationship within the leaf and that consequently such infections are unable to develop beyond the initial stages, the fungus dying as the leaf matures. That such a susceptible period exists and that later the tissues become resistant to any further spread of the fungus is suggested by the well defined boundary which always exists between healthy and diseased areas on the mature leaf. This resistance seems to be correlated with the degree of maturity of the tissue inasmuch as the tip which matures earliest (*2*) is the most resistant part of the leaf. A histological study of abortive infections on rapidly-growing leaves is being made with the hope of finding out something further of the host-parasite relationships.

These results indicate further that the prevalence of leaf curl following cold wet springs is to be accounted for in large part by the slow growth rate associated with them being optimum for the later stages of the infection process rather than to them offering peculiarly optimum conditions for the initiation of infection.

LITERATURE CITED

1. FITZPATRICK, R. E. The life history and parsitism of *Taphrina deformans*. Sci. Agric. *14* : 305-326. 1934.
2. ——————. The ontogeny of the peach leaf. Trans. Roy. Can. Inst. *20* : 73-76. 1934.

Résumé

Nouvelles études sur le parasitisme du *Taphrina deformans*. R. E. Fitzpatrick, Vineland Station, Ontario.

Il a été démontré par des recherches préliminaires sur des pêchers plantés en pots que les phases initiales de l'infection par *Taphrina deformans* peuvent se produire à une température de 50° F. et jusqu'à 70° F., mais que la gravité de la maladie (l'enroulement des feuilles du pêcher) est grandement influencée par les conditions dans lesquelles les plantes sont cultivées après que l'on sait que la pénétration s'est produite. Aux hautes températures (70° F.), lorsque le développement des feuilles était rapide, les relations parasitaires n'ont pas été maintenues et le champignon a été détruit. Aux températures plus basses (50° F. — 60° F.), lorsque le développement des feuilles était lent, le champignon a pu s'établir plus promptement et il en est résulté une haute fréquence de l'enroulement des feuilles.

SECONDARY TUMOR FORMATION ON HERBACEOUS HOSTS INDUCED BY *PSEUDOMONAS TUMEFACIENS* Sm. and Town.[1]

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INTRODUCTION

A series of 300 two-year old apple trees in the experimental plots at the Iowa State College, which had been inoculated with *Pseudomonas tumefaciens* Sm. and Town. the previous summer, showed the development of conspicuous swellings on several of the trees during the summer of 1929. These swellings, which were, in all probability, secondary tumors, were situated from eight to ten inches above the point of inoculation and were from one-fourth to three-fourths of an inch in diameter, but were not convoluted externally as is a typical crowngall.

It is possible that the swellings found might be other than secondary tumors. However, various facts seem to point to the secondary tumor as the explanation. The soil in which the trees were growing had been steam sterilized for 40 minutes at 120 pounds pressure with an inverted pan before the trees were planted. This fact would reduce the possibility of any natural infection coming from the soil. A close examination of these swellings showed that the bark layer was not broken. Therefore, in all probability they were not caused by callus formation induced by a wound. The tumors were split and examined to determine whether insect irritation could have been the cause. No evidence of insects or insect injury was found.

While it appears that these swellings were secondary tumors, the exact manner of their formation is questionable. In considering the possible methods of the formation of secondary tumors, it does not seem probable that tumor strands, as reported by Smith *et al* (*12*), could have forced themselves through the apple tree tissue to such a distance, and also no evidence of tumors was found between the points of inoculation and the secondary tumors. The explanation as given by Riker (*10*), Robinson and Walkden (*11*) and Levine (*6*) that secondary tumors are caused by elongation of the growing point after inoculation in this region does not apply since no growing point was involved here. Also it does not seem likely that the wound made when inoculating could have exerted such an influence by a release of liquid in the intercellular spaces as reported by Riker (*9*) and Invanoff and Riker (*5*), nor would it be probable that the organisms had migrated through the intercellular spaces to such a distance as zoogloeae as reported by Robinson and Walkden (*11*) and Hill (*3*). The possibility that the crowngall organism might pass through the xylem of the vascular system of a plant and form tumors a considerable distance from the point of entrance suggested itself and was studied. Hill (*3*) and Hamdi (*2*) have suggested that *Ps. tumefaciens* could migrate in the xylem

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of a plant. Hill *et al* (*4*) have found zoogloeae migrating short distances in the vessels, while Riker (*9*) states that the organism may travel in some parts of the vascular bundles if the conditions are favourable.

MATERIALS AND METHODS

Experiments were started at the Iowa State College and continued here to develop the concept of vascular invasion of the host by *Ps. tumefaciens*. Herbaceous plants were chosen for experimentation inasmuch as they are easily grown and react rapidly to the crowngall organism. Four herbaceous plants have been used; namely, Paris daisy (*Chrysanthemum frutescens* L.), tomato (*Lycopersicon esculentum* Mill. var. Dwarf Stone), tobacco (*Nicotiana tobaccum* L.) and *Bryophyllum calycinum* Salisb. The culture of *Pseudomonas tumefaciens* used throughout the experiments was isolated by Dr. J. H. Muncie from a gall on an apple tree in 1926 and designated by him No. 468. The fact that galls were obtained in every case at the point of inoculation would indicate the virulence of the culture.

Throughout the experiments two types of inoculation were employed: the broth-culture method and the needle method. In the broth-culture method tomato plants 10–12 inches, Paris daisy plants 4–6 inches, tobacco plants 10–12 inches, and Bryophyllum plants 8–10 inches high were used. The plants were cut off one half inch above the soil and stood with the lower half inch of the stem in a two-day-old broth culture of *Ps. tumefaciens*. They were then set in the sunlight, to induce transpiration, for four hours. The plants were then taken out and all the leaves except the topmost two removed by cutting the petiole of each at its juncture with the stem. In all cases the knife used for cutting was flamed before each cut. These cuttings were then set in sand which had been steam sterilized at 20 pounds pressure for one hour, and were kept shaded for the first week.

TABLE 1.—EFFECT OF LENGTH OF TRANSPIRING PERIOD ON THE MOVEMENT OF *Ps. tumefaciens* THROUGH THE STEM OF DWARF STONE TOMATO PLANTS

Time	Number of cuttings	Location of galls				
		Base	1st node	2nd node	3rd node	4th node
¼ hr.	40	40	10	34	11	0
½ hr.	40	35	20	35	0	0
1 hr.	40	37	37	14	15	0
2 hrs.	40	40	20	40	18	0
4 hrs.	40	40	36	40	40	26

A preliminary experiment was conducted in order to determine the correct transpiring period for the broth-culture method in which the cut plants were allowed to remain in the broth culture of *Ps. tumefaciens* and in the sunlight for different lengths of time. Table 1 shows the results from this experiment. It is evident that the four-hour period resulted in the larger number of secondary tumors being formed. Periods longer than four hours were tried but did not show any perceptible increase in the number of secondary tumors.

The needle method is much simpler and is the usual method of inoculating hosts with the crowngall organism. A small amount of a three-day-old agar culture of the organism is taken on the tip of a spear-point needle. This mass of bacteria is put on the host at the desired place and

introduced into the tissue by a single stab through the mass or by several pricks into the tissue through the mass of bacteria. The operation wounds the tissue of the host and introduces the organism. Plants that have been inoculated are then placed in a moist chamber for three days, after which they are returned to the greenhouse bench.

Many isolations were made throughout the course of these experiments. All isolations were made with the bile crystal violet medium following Patel's (*8*) technique for the isolation of *Ps. tumefaciens*. Better results were obtained in plating when a sterile salt solution of 5 gms. sodium chloride and 1 gm. magnesium sulfate per liter of distilled water was used in place of sterile distilled water. Colonies were selected from the poured plates and transferred to potato dextrose agar slants. These cultures were then inoculated into tomato to prove the presence of *Ps. tumefaciens*.

Material for histological study was killed in the acetic acid-formalin-alcohol solution and dehydrated with acetone. Safranin with a counterstain of fast green S.F. was used for staining sections.

INOCULATION STUDIES

Evidence as to the movement of the organism through the host stem was sought in two ways. In the first case efforts were made to isolate the organism from the stem at various distances from the point of inoculation, while in other experiments the formation of secondary tumors was considered to be possible evidence of movement of the organism.

Results of Isolations Following Inoculation

Distance of Movement of Ps. Tumefaciens

Three series of 30 plants each of tomato, Paris daisy and Bryophyllum plants were inoculated by the broth-culture method. The isolations from the tomato cuttings immediately after treatment showed 100% positive for *Ps. tumefaciens* at two and four inches from the base of the cutting, while isolations at a distance of six inches were 8% positive. In the case of the Bryophyllum cuttings 100% of the isolations showed *Ps. tumefaciens* at a distance of two inches, and at three inches 25% of the isolations were positive. With Paris daisy cuttings all isolations at one inch above the base were positive, with only 3% of the trials at two inches resulting in *Ps. tumefaciens* being obtained.

The movement of the crowngall organism down the stem and the possible influence of transpiration stream were observed on tomato plants. Two series of 25 plants each were inoculated by attaching tubes of a two-day-old broth culture at the tip of the stem, while two other series were inoculated at two of the lateral leaf petioles of each plant for four hours. Isolations were made at one inch and two inches below the cut tip of the plant. Positive results were obtained one inch below the point of introduction of the organism and negative results at the second place of isolation. When the organism was introduced through the petioles, which were one and one half inches long, isolations were made at the point of union of the petiole and stem, one and two inches below, and one and two inches above the juncture. Positive isolations were obtained at the juncture of

the petiole and stem and also one inch above. The other points of isolation, however, gave negative results. These results would indicate that *Ps. tumefaciens* moves more rapidly up the stem and is influenced by the transpiration stream contrary to Hill (*3*), who reports that the migration was independent of the flow of sap in the vessels.

To determine whether *Ps. tumefaciens* travelled in the xylem of the host plant, 50 Bryophyllum plants were ringed to remove the phloem and cortex. The ringed portion was three-fourths of an inch wide. The cuttings were then inoculated by the broth culture method, and after treatment isolations were made from the stem one inch above the ringed portion. In all the isolations *Ps. tumefaciens* was recovered in practically pure culture. The results of this experiment would indicate that *Ps. tumefaciens* travels through the vessels of the xylem, inasmuch as the distance travelled was over 500 mm., while Hill (*3*) and Ivanoff and Riker (*5*) report the organism to travel as zoogloeae through the intercellular spaces of the cortex and pith to a distance of 3 to 5 mm. in four hours. The rate of movement of zoogloeae in the vessels as reported by Hill *et al* (*4*) is also much slower.

Longevity of Ps. tumefaciens within host tissue

The longevity of *Ps. tumefaciens* within the host tissue without producing pathic events is questionable. One set of 100 tomato plants were inoculated by the broth-culture method and isolations were made from six cuttings each week at points three, five and seven inches above the base of the cutting. The experiment was repeated three months later. Isolations continued for 10 weeks in each case, at which time the cuttings were starting to die from lack of nutrients as they were being grown in steam sterilized sand.

These isolations showed that after 10 weeks *Ps. tumefaciens* could still be isolated from an apparently normal internode of the tomato cutting. Isolations made during both 10-week periods from the point three inches above the base of the cutting showed 92% as positive and from the point five inches above 60%, while the isolations from the 7-inch distance were all negative. The growth of *Ps. tumefaciens* on the agar plates was of interest. In the case of isolations from the 3-inch lot the colonies appeared from two to three days after the isolation was made. The plates made from the 5-inch lot never showed colonies until 4 or 5 days after the isolation. The cause for this difference in the time of appearance of the colonies on the agar plates might be that the organisms farther up the stem had become attenuated. However, inoculation of the transferred colonies into tomato plants to establish the presence of *Ps. tumefaciens* did not show any difference in the virulence of any of the cultures. It was also noticed that the isolations for the 8th, 9th and 10th weeks were a day later in developing colonies of the organism than was normal.

The results of the various experiments to determine the distance of movement of *Ps. tumefaciens* through the host show that the organism moves rapidly in the xylem to a distance of at least six inches in tomato, three inches in Bryophyllum, and two inches in the Paris daisy. The movement of the organism down the stem through the xylem reaches a distance of one inch in four hours, while the transpiration stream aids in the movement of the organism upward. Check inoculations were made in every experiment, using sterile broth. All isolations in the check treat-

ments were negative for *Ps. tumefaciens*, while over 95% of the plates remained sterile.

Formation of Secondary Tumors Following Inoculation

A further test of the distance of movement of *Ps. tumefaciens* through the host plant is the formation of secondary tumors. Although the previous experiments showed that *Ps. tumefaciens* could move through the host plant for a certain distance, they did not indicate whether the organism could induce secondary tumors at these various distances from the point of entrance.

Inoculation by the broth-culture method

At various times during a period of two years, six series of 100 tomato plants each have been inoculated by the broth-culture method and final notes taken 35 days after the start of the experiment. In most cases it was observed that tumors had started to form on various cut petioles within 12 days after inoculation. Table 2 shows a summary of the results obtained from the six experiments.

TABLE 2.—DISTRIBUTION OF SECONDARY TUMORS ON TOMATO CUTTINGS INOCULATED BY THE BROTH-CULTURE METHOD WITH *Ps. tumefaciens*

Number of cuttings	Position of tumor	Cuttings with tumors	
		Number	Percentage
600	Base of cutting	600	100.0
600	1st node	570	95.0
600	2nd node	510	85.0
600	3rd node	474	79.0
600	4th node	390	65.0
600	5th node	306	51.0
436	6th node	151	34.6
321	7th node	93	29.0
164	8th node	39	23.7
45	9th node	8	17.7
600	Extruding on internode. Lower half of stem	592	98.6
600	Extruding on internode. Upper half of stem.	387	64.5
100	Check	0	0

These results show that secondary tumors are found as far as the 9th node from the base, which is about 16 inches from the place of entrance. It is noticed that the number of cuttings is less beginning with the 6th node. This has happened because not all of the cuttings used were of the same height. It is also observed that the percentage of cuttings showing secondary tumors at the cut petioles is less as the distance from the point of entrance increases. Table 2 further shows that secondary tumors were formed on the uninjured internodes of the inoculated cuttings. As many as 12 of these tumors have been observed on one plant. The distribution of these secondary tumors found extruding through normal tissue is approximately the same as the tumors formed at the cut petioles.

Two series of 100 tobacco plants each were treated similarly to the tomato plants. The results of these experiments show that the percentage

of cuttings with secondary tumors at the cut petiole varied from 92% at the 1st node to 14.5% at the 7th node, a distance of 12 inches. All of the cuttings produced tumors at the base, while 18% of the cuttings showed secondary tumors extruding on the internode. These results are in accord with those obtained with the tomato plants.

Similar experiments to those carried on with tomato and tobacco plants were conducted with Bryophyllum and Paris daisy plants. In these experiments galls were formed at the base of all of the cuttings, but no secondary tumors were observed. However, the isolation experiments showed that *Ps. tumefaciens* had moved a distance of three inches in the Bryophyllum plants and two inches in the Paris daisy plants.

Effect of Wounding on the Formation of Secondary Tumors

Three experiments were conducted with tomato and tobacco plants inoculated by the broth-culture method, in which wounds were made with a sterile knife on the fourth internode (about five inches) from the base of the cutting. Tomato cuttings wounded within one week after inoculation showed the formation of tumors at 94% of the wounds within four weeks, while wounding three weeks after inoculation showed tumors at 45% of the wounds in the same period of time. In the case of the tobacco plants the percentage of tumors formed at the wounds varied from 57% on the cuttings wounded immediately after inoculation to 5% on the cuttings wounded 35 days after inoculation. In the above experiments transverse wounds were made to a depth of about one third of the diameter of the stem.

The wounds made in the above experiments would, of course, wound both the vascular bundle and also the surrounding medullary rays. In order to determine if wounding in the medullary ray would induce tumor formation two series of 100 young tomato plants each were inoculated by the broth culture method. A study of the vascular skeleton of the tomato plant showed the presence of a ring of vascular bundles separated by medullary rays. Half of each series was wounded with a single needle stab through the medullary ray while the other half of the series was wounded through the vascular bundle. Each cutting was wounded at five places from three to eight inches from the base. In Table 3 is shown the com-

TABLE 3.—EFFECT OF PLACE OF WOUNDING INOCULATED TOMATO CUTTINGS ON THE FORMATION OF SECONDARY TUMORS BY *Ps. tumefaciens*

Height from base of cutting	Wounded in vascular bundle				Wounded in medullary ray			
	Number of cuttings	Number with tumors	Number without tumors		Number of cuttings	Number with tumors		Number without tumors
			Stab in vascular bundle	Stab in medullary ray		Stab in vascular bundle	Stab in medullary ray	
3 inches	100*	67	14	19	100	7	0	93
4 inches	100	69	12	19	100	8	0	92
5½ inches	100	74	12	14	100	8	0	92
6½ inches	100	65	18	17	100	4	0	96
8 inches	100	58	27	15	100	3	0	97

*Cuttings wounded one week after inoculation and final notes four weeks later.

bined results of the two experiments. The percentage of wounds in the vascular bundle that resulted in the formation of tumors varied from 82.7% at three inches from the base of the cutting to 68.2% at a distance of eight inches. Some cuttings showed tumors at every wound and only six cuttings showed no tumors at any of the wounds. The wounds made through the medullary ray did not result in the formation of secondary tumors. These results indicate that if *Ps. tumefaciens* is in the vascular system of a plant, wounds which injure this tissue will probably result in the formation of tumors. Also these experiments again show that the percentage of tumors becomes smaller as the distance from the point of entrance increases.

In another experiment 100 tomato cuttings that had been inoculated by the broth culture method were each cut off six inches above the base with a sterile knife nine weeks after inoculation. These upper portions of the cuttings were then set in steam-sterilized sand. Examination of these after three weeks showed that 76% of them had produced galls at the base. These results would indicate that it would not be advisable to take cuttings from a plant severely infected by *Ps. tumefaciens*.

Inoculation by the needle method

The development of secondary tumors following the inoculation of *Ps. tumefaciens* by the needle method has been studied with respect to the four hosts used in previous experiments.

Two series of 100 tomato cuttings each were inoculated at the base with *Ps. tumefaciens* by the needle method and then set in steam-sterilized sand. The cuttings in each case were examined after 30 days. All of the cuttings showed galls at the base, while the first node showed 17%. Tumors were not found at any of the other nodes, and no tumors were observed extruding on the internodes. In comparing these results with those from the broth-culture method of inoculation, it would seem that the formation of secondary tumors at a distance from the primary tumor was determined by the number of organisms gaining entrance to the vessels of the xylem.

In another experiment tobacco plants were inoculated by the needle method in the growing point and at different distances up to three inches below. Ninety-four per cent of the plants inoculated in the growing point showed the presence of secondary tumors. This high percentage of secondary tumors was expected, however, as Riker (*10*) and Robinson and Walkden (*11*) have shown this to be a way in which secondary tumors may be formed. Inoculation one-half inch below the growing point resulted in 60% of the plants showing secondary tumors; one inch below, 50%; two inches below, 40%; and three inches below, 80%. These secondary tumors were from one-fourth to two inches from the gall at the point of inoculation. Of the secondary tumors formed, 74% were above the point of inoculation and 26% were below. The former were distributed at greater distances from the point of inoculation. This fact also supports the contention that the transpiration stream has an influence on the movement of *Ps. tumefaciens* in the vessels of the host. One other fact indicated by inoculations in this experiment is that wounding of the stem with many needle stabs in inoculation is more conducive to secondary tumor formation than a single stab of the needle, although severe wounding of the

stem did not perceptibly increase the number of secondary tumors produced. This fact is explained, however, by the larger number of vessels that would be broken in the wounding of an area of the stem one-fourth inch square.

Paris daisy plants were inoculated by the needle method in the growing point, one-fourth inch and two inches below the growing point. Thirty per cent of the plants inoculated in the growing point developed secondary tumors. The inoculation one-fourth inch below the growing point resulted in the production of secondary tumors on 34% of the plants, while in the inoculation two inches below, 10% of the plants showed secondary tumors. In all cases galls were formed at the point of inoculation.

Inoculations were made on Bryophyllum plants in the growing point and one-half, one, and two inches below the bud. No definite secondary tumors were formed, although in 52% of the plants inoculated in the growing point, the resulting galls extended over two and in some cases three internodes. In all other plants, galls were formed at the point of inoculation.

In comparing these two methods of inoculation for secondary tumor formation, the number of tumors formed and the distance travelled by *Ps. tumefaciens* is much greater in the case of the broth-culture method. However, this difference should be expected as the broth culture method introduces a great number of organisms into the vascular tissue, while in the needle method only comparatively few would be introduced and then only if the vascular tissue was broken by the needle.

HISTOLOGICAL STUDIES

The investigations so far have been concerned with the reactions of the host when inoculated with *Ps. tumefaciens* in various ways. This information, however, does not explain why some hosts show a larger number of secondary tumors than others, what tissues are definitely the place of migration of the organism, or how the secondary tumors originate. Histological studies of the hosts and of secondary tumors have been made in an effort to explain these points.

Normal Anatomy of the Four Hosts

In cross section, the young stems of the four hosts show a peripheral ring of vascular bundles separated by medullary rays. As the stems increase in age interfascicular cambium forms so that a cross section shows a complete ring of vascular tissue. Examination of the xylem shows that this tissue is composed chiefly of xylem parenchyma with a relatively small number of vessels occurring in groups.

The relation of the leaf trace to the vascular skeleton of the stem among these plants is ot two general types. In the tobacco and tomato plants the leaf traces are branches of the main vascular bundles running through the stem similar to the vascular system of the potato plant as reported by Artschwager (*1*). In the Paris daisy and Bryophyllum plants it appears that the leaf traces are strands of vascular tissue extending from the crown of the plant, so that the xylem in one petiole has no connection with the xylem in any other portion of the plant.

Another point of interest is the size of the vessels in each host. The vessels in tomato and tobacco vascular tissue have approximately twice the diameter of the vessels found in the Paris daisy and Bryopyhllum. Also it was found that the vessels in the upper one-third of the stems of tomato and tobacco were about one-half the diameter of most of the vessels found in the older portions. In the case of Paris daisy and Bryophyllum the vessels in the upper portion of the stem were about two-thirds of the diameter of the vessels in the older portion of the stem. Also it was found that in the xylem region of the stems of tomato and tobacco plants there were twice as many vessels per unit area as were found in the Paris daisy and Bryophyllum plants.

This difference in vascular anatomy between tomato and tobacco plants and Paris daisy and Bryophyllum plants and the difference in the size and number of the vessels probably explain the difference in the number of secondary tumors formed on the plants in each group when inoculated by the broth culture method. The smaller number of secondary tumors formed on the upper one-third of the inoculated stems might be explained by the fact that the vessels are smaller in this region and the number of organisms that could move here would be less.

Presence of Ps. tumefaciens in the vessels

The results obtained from the various inoculation experiments indicate that *Ps. tumefaciens* moves in the vessels of the host. Observation of the organism in the vessels would be more definite proof that such is the case. Free-hand selections of tomato stems inoculated by the broth-culture method with a suspension of the stained organism did not show the organisms, although the walls of the vessels were stained. Sections were also made from tomato stems inoculated by the broth-culture method and then stained. In some instances *Ps. tumefaciens* was thought to be found in the vessels. The staining reaction of the organism is practically the same as the host tissue, so a further experiment was conducted in which a stained suspension of *Mycobacterium berolinensis* was introduced. This organism is approximately the same size as *Ps. tumefaciens* and is acid fast. Free-hand sections of tomato stems inoculated with *M. berolinensis* showed the organism to be present in the vessels up to six inches above the point of entrance.

Origin of Secondary Tumors

Experiments have shown that when a plant which had been previously inoculated by the broth-culture method is wounded so as to break the vessels at a point above the place of inoculation, secondary tumors frequently form at this point. It appears that the breaking of the vessels allows the organisms to accumulate with a consequent action of the organism in inducing a tumor. Microscopical examination of sections of tomato stem inoculated by the broth-culture method has shown internal tumors in the protoxylem region. Plate I A shows a small internal tumor. These internal tumors are usually situated some distance from the surface of the stem and it is doubtful if they would ever reach the surface. Further, these internal tumors appear to originate from the vessels of the protoxylem that have been broken by elongation of the stem.

The formation of secondary tumors that appear on the surface of the uninjured internode of the stem is more difficult to explain. Plate I

B shows a longitudinal section of a tomato stem showing a secondary tumor starting to form. A small tumor is forming adjacent to the vessels, and above and below other vessels have formed. Also it appears that the organism has also influenced the tissue just outside of the longitudinal fiber and also the tissue at the surface of the stem. A cross section of a tomato stem showing a young tumour apparently originating from the xylem and forcing its way outward is shown in Plate II A. Tracheids can be seen connecting this growth with the vessels of the xylem.

An older secondary tumor shows more clearly the method of development. Plate II B is a diagrammatic drawing made with the aid of a camera lucida. Here is shown a definite strand of tracheids originating from the xylem and then being distorted and broken up in typical crown-gall fashion. Structures resembling adventitious roots were found in connection with many of the secondary tumors examined. It is probable that an accumulation of *Ps. tumefaciens* in the vessels acts in stimulating the formation of adventitious roots, through the vessels of which the organisms pass. After penetrating the phloem and the fiber ring into the cortex, the adventitious growth, under stimulus of the organism, is finally distorted and formed into gall tissue as it breaks through the epidermis, thus forming a tumor on the surface of the stem. Recently Levine (*7*) has reported the presence of young adventitious roots in crowngall on Opuntia. However, he reports that these young rootlets become abortive and necrotised.

DISCUSSION

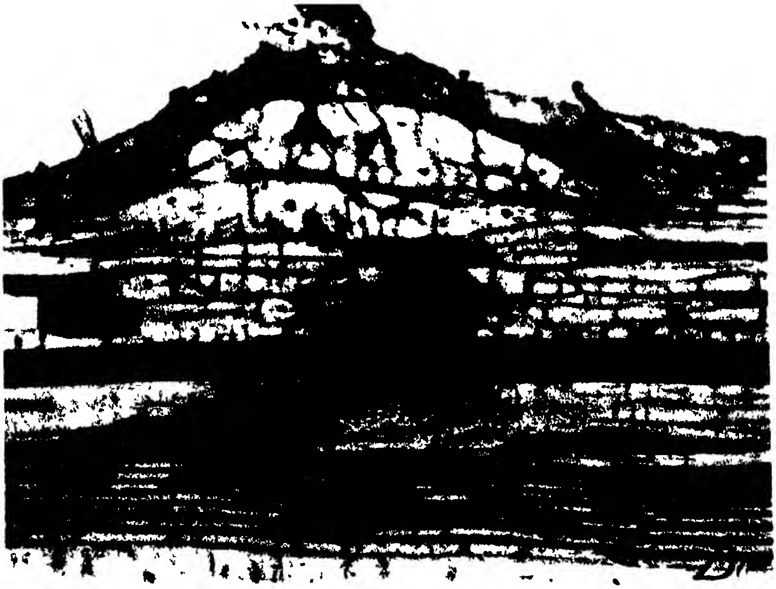
The passage of phytopathogenic bacteria through the vessels of the xylem of the host is not new. It is well known that in many bacterial diseases the organisms move through the vessels. The probability that *Ps. tumefaciens* could travel through the vessels of the host has been suggested by Riker (*9*), Hill (*3*), Hill *et al* (*4*) and Hamdi (*2*). Definite proof has been obtained that such is the case. The distance of movement has been shown, by isolation of the organism, to be as far as six inches in four hours and, from the location of secondary tumors, apparently as far as 16 inches. This is a much greater distance than that previously reported. Hill (*3*) and Ivanoff and Riker (*5*) showed that the organism could move as far as four millimeters in four hours, but after that time the movement became less, while Hill *et al* (*4*) report the movement of zoogloeae in the vessels to a distance of 2.3 millimeters in 15 minutes. It appears that *Ps. tumefaciens* can move through the vascular system of the host but is limited by the anatomy of the xylem and the size of the vessels.

The movement of *Ps. tumefaciens* through the vessels is aided by the transpiration stream. This is indicated by several facts. In the broth-culture method of inoculation more secondary tumors were formed, and also at a greater distance from the point of entrance, as the length of time the plants were kept in the sunlight was increased. When inoculated into the tip of tomato plants the organism showed only a very short movement down the stem. When the organism was introduced into a petiole it was recovered above the node and not below. Further evidence was obtained from the inoculation of the tobacco plants by the needle method. In this a much larger percentage of tumors formed above the point of inoculation and had a wider distribution along the stem than those formed below.

DESCRIPTION OF PLATES

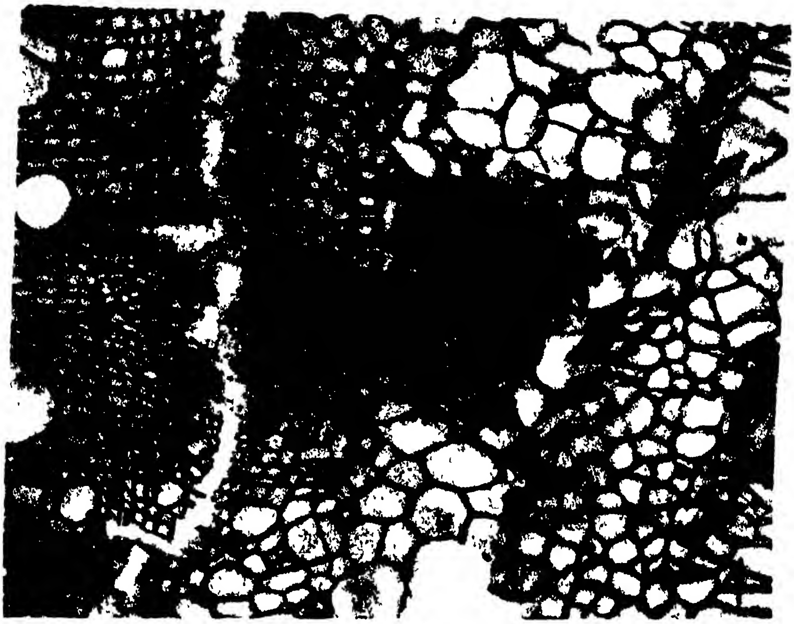
PLATE I

A. Longitudinal section of a tomato stem 35 days after inoculation showing a small internal secondary tumor in the protoxylem region × 128

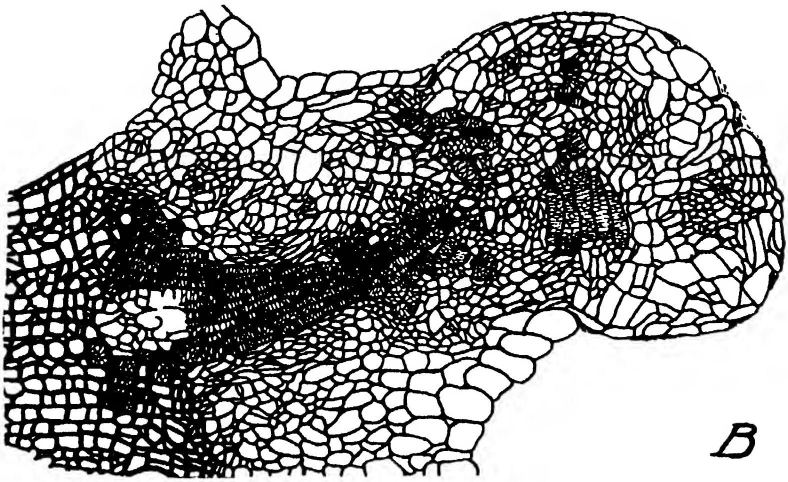


B—Longitudinal section of a tomato stem showing a young secondary tumor forming adjacent to the xylem and influencing the cortex and epidermis. × 64.

PLATE II



A.—Cross section of a tomato stem showing a young secondary tumor originating from the xylem and forcing its way outward. × 128.



B—Camera lucida drawing of a cross section of a tomato stem showing an extruding secondary tumor that originated from the xylem and has formed on the surface of the stem. × 110.

These results, however, do not support Hill's (*3*) statement that "the bacteria were found in the vessels both above and below the puncture, indicating that the migration was independent of the flow of sap in the vessels."

The question of the longevity of the crowngall organism in host tissue without producing pathic events is of interest. Isolations showed that *Ps. tumefaciens* could be obtained from apparently normal internodes of a tomato stem for 10 weeks following inoculation. It is probable that the organism could live longer than this period inasmuch as 75% of the isolations made the tenth week were positive. However, the organism appeared to be losing its vitality as it took one to two days longer for the colonies to appear after isolations made the eighth, ninth and tenth weeks. It is possible that in making the isolations, an internal tumor was included in the tissue taken for isolation. If such was not the case, apparently *Ps. tumefaciens* had accumulated and remained inactive in some of the vessels. The longevity of the organism within the host tissue is also important with respect to the formation of tumors on cuttings. Cuttings made from tomato cuttings that had been inoculated nine weeks previously showed that 76% of them developed crowngall in three weeks. It appears, from this information, that it would probably not be advisable to take cuttings, or use other methods of vegetative reproduction, from plants that were severely infected with *Ps. tumefaciens*.

The results show that there are three different ways in which secondary tumors may develop as a result of vascular infection. In the first case, if wounds occur from the exterior which break the vessels, the organisms are freed and induce gall formation. In this case a wound is present and the formation of the tumor is identical with that of galls formed by the usual needle inoculation into the cortex of the stem. Another place of secondary gall formation is the protoxylem region. Here internal secondary tumors are found in connection with the broken vessels of the protoxylem. Smith *et al* (*12*) report the presence of tumor strands in the protoxylem region. However, many of the photomicrographs in their article appear to suggest tumor formation from vascular infection. In several of the plates in Smith *et al* (*12*) ruptured vessels can be observed in connection with the tumor. It is possible that many of the so-called tumor strands reported by Smith *et al* (*12*) to be present in the protoxylem region were internal secondary tumors formed at the places where the vessels had been ruptured due to elongation of the stem. In the third instance secondary tumors are found extruding on the surface of the internodes of inoculated stems. These secondary tumors are not present until about three weeks after inoculation. They increase in number as the time from the date of inoculation increases. It appears that the organisms accumulate in a few of the vessels due to mechanical plugging or at imperfections in the vessels. This group of organisms then seems to induce the formation of a rootlet which forces its way through the cortex and as it appears on the surface of the stem it is disorganized into a tumor. *Ps. tumefaciens* has been isolated from these secondary tumors and it is probable that the organism passes through the vascular tissue of these rootlets. The size of these extruding secondary tumors varies from one-sixteenth to one-fourth of an inch in diameter depending on their age. Young rootlets, or

the remains of the vascular system of such are found in connection with a majority of the extruding secondary tumors examined. As many as four young rootlets about one millimeter long have been observed in the formation of this kind of tumor. When such is the case the tumors are larger and appear to be made up of smaller centers of gall tissue. Several such galled areas have been found to be one-half inch long and one-fourth inch wide.

From the information available with regard to secondary tumor formation there appears to be three ways in which this kind of tumor may form. In the first place, inoculation of plants in the growing point result in the formation of secondary tumors due to the elongation of the inoculated tissue as has been shown by Riker (*10*), Robinson and Walkden (*11*) and Levine (*6*). Secondly, when inoculations are made in the cortex of the stem the organisms migrate short distances from the point of inoculation as zoogloeae, which has been reported by Robinson and Walkden (*11*), Hill (*3*) and Ivanoff and Riker (*5*). Then, lastly, when *Ps. tumefaciens* gains entrance to the vessels, it may move considerable distances and induce secondary tumors, as reported in this work.

It must be remembered, however, that of all this experiment work (Smith *et al* (*12*), Riker (*9*, *10*), Robinson and Walkden (*11*), Levine (*4*), Hill (*3*), Ivanoff and Riker (*5*) and herein reported) has probably been done with organisms in excess over those present in nature. However, wounds which penetrate the xylem offer the possibility even in nature of helping to induce secondary tumors on those plants infected by *Ps. tumefaciens*. Also should the organism gain entrance to the vessels, extruding secondary tumors could be formed. On the other hand, it is very seldom that secondary tumors are observed under natural conditions. The one exception might be the cane gall of raspberry.

SUMMARY

The movement of *Ps. tumefaciens* through the vessels of the xylem of the host is demonstrated. This movement is influenced by the transpiration stream, the number and size of the vessels and the vascular anatomy of the stem of the host.

Pseudomonas tumefaciens has existed in the tissue of apparently normal internodes of tomato plants without producing visible pathic events for ten weeks.

Secondary tumors arising from vascular infection by *Ps. tumefaciens* are of three kinds: (1) external tumors, which arise from wounds from the exterior, which break the vessels; (2) internal tumors at breaks in the vessels of the protoxylem; (3) extruding tumors, which originate from the xylem as adventitious growths.

LITERATURE CITED

1. Artschwager, E. F. Anatomy of the potato plant, with special reference to the ontogeny of the vascular system. Jour. Agri. Res. *14* : 221-252. 1918.
2. Hamdi, H. Uber die histogenese, Ban und Natur des sog. Pflanzenkrebses und dessen metastasen. Zeitschr. Krebsforch. *30* : 547-552. 1930.
3. Hill, J. Ben. The migration of *Bacterium tumefaciens* in the tissue of tomato plants. Phytopath. *18* : 553-564. 1928.
4. ——————, W. H. Brittingham, Frances P. Gibbons, and Grace W. Watts. Further notes on *Bacterium tumefaciens* and its host relationship. Phytopath. *20* : 179-186. 1930.

5. IVANOFF, S. A. and A. J. RIKER. Studies in the movement of the crowngall organism within the stems of tomato plants. Phytopath. *20* : 817-828. 1930.

6. LEVINE, M. The so-called strands and secondary tumors in the crowngall disease. Phytopath. *15* : 435-451. 1925.

7. ———— . Experimental production of crowngall on Opuntia. Phytopath. *24* : 929-937. 1934.

8. PATEL, M. K. An improved method of isolating *Ps. tumefaciens* Sm. and Town. Phytopath. *16* : 577. 1926.

9. RIKER, A. J. Some relations of the crowngall organism to its host tissue. Jour. Agr. Res. *25* : 119-132. 1923.

10. ————. Some morphological responses of the host tissue to the crowngall organism. Jour. Agr. Res. *26* : 425-436. 1923.

11. ROBINSON, W. and H. WALKDEN. A critical study of crowngall. Ann. Bot. *37* : 299-324. 1923.

12. SMITH, E. F., NELLIE A. BROWN and LUCIA MCCULLOCH. The structure and development of crowngall. U.S. Dept. Agr. Bur. Pl Ind. Bul. 255. 1912.

Résumé

Formation de tumeurs secondaires sur des hôtes herbacés provoquée par *Pseudomonas tumefaciens* Sm. et Town. R. F. Suit et E. A. Eardley, Service de pathologie végétale, Collège Macdonald, P.Q.

La circulation de *Ps. tumefaciens* à travers les vaisseaux du xylem de l'hôte est démontrée. Ce mouvement est influencé par le torrent de la transpiration, le nombre et la dimension des vaisseaux et l'anatomie vasculaire de la tige de l'hôte. Le *Ps. tumefaciens* a existé pendant dix semaines dans le tissu d'internodes apparemment normaux des plants de tomates sans produire de symptômes pathogènes visibles. Les tumeurs secondaires naissant de l'infection vasculaire par *Ps. tumefaciens* sont de trois sortes: (1) tumeurs externes qui naissent des plaies de l'extérieur, et qui rompent les vaisseaux; (2) tumeurs internes aux ruptures dans les vaisseaux du protoxylem; (3) tumeurs faisant saillie qui naissent du xylem sous forme de végétations adventices.

MOULDY CORE IN GRAVENSTEIN APPLES[1]

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Apple growers in the Annapolis Valley are subject to severe losses in some seasons due to the heavy drop of Gravensteins in late August and early September just before the proper date for harvesting this variety. A large proportion of the fallen fruit has an opening in the blossom end leading into the apple and the core region is usually invaded by moulds. These conditions have been known to growers for years and many pick early to avoid losses. The trouble has been brought more forcibly to their attention in recent years as the result of planting and grafting with the red bud sports of this variety, because the apples that tend to drop early develop high colour, and it is from amongst the finest appearing apples on the trees that the loss takes place. The most severe losses recorded were at the average rate of one barrel per tree for a block of 250 trees.

REVIEW OF LITERATURE

It was found in a review of the literature that openings at the calyx end and moulds in the core were well known phenomena. Sorauer (*10*) noted the susceptibility of cores with woolly streaks to attacks by organisms. Longyear (*8*) considered that structural peculiarities rendered certain varieties of apples subject to "blackened seed cavities" and associated a blossom end rot caused by *Alternaria* with calyx peculiarities. A number of workers since have reported the presence of organisms in the cores of apples. O'gara (*9*) in his work on water core of apples mentions *Alternaria* sp. as gaining entrance through cracks. Cook and Martin (*6*) associated "Blossom end and core rot" with *Alternaria* sp. Brooks, Cooley and Fisher (*3*) consider *Alternaria* sp. the most common source of core rots, the entrance of the organism "being favoured by the open calyx that frequently characterizes the apples from irrigated orchards." Heald (*7*) isolated organisms from Stayman Winesap cores and found that *Alternaria* sp. predominated.

Carne, Pittman and Elliott (*4, 5*), describe four disorders of the variety Cleopatra; namely, woolly streak, hollow core, split core, and mouldy core. They stress the prevalence of split core in years of light crop and consider that these disorders are caused by too rapid and irregular growth. The opinion has been expressed by Brittain and Blair (*1*) and Brittain and Eidt (*2*) that the heavy drop of Gravensteins is connected with open calyx, mouldy core, and low seed content, and that all are correlated with faulty or inadequate pollination. The latter consider that mouldy core is due to the failure of the calyx tube to close and quote Miss Tetley's observations (*11*) that the young apples of the variety Bramley's Seedling have a tube through the style that connects the calyx with the core and that these may or may not become closed during the growth of the apple. They also report Boskoop as affected and point out

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that Gravenstein, Boskoop and Bramley's Seedling are triploids and consider that "This is of interest in view of the observed fact that in triploids, abnormalities are likely to develop late in the life cycle."

Core Characteristics

Woolly Streak.—White woolly streaks extending across the endocarp (hard walls of the core) are very common, particularly in the varieties Gravenstein, Red Delicious, and Ortley (known as Cleopatra in Australia). The endocarp is pulled apart in some cases as much as one-eighth inch and the growth of the cells of the flesh underneath the break causes the white appearance.

Hollow Core.—This is common in a number of varieties. The five carpillary chambers are pulled apart so that a common seed cavity is formed with five more or less shallow lobes. In pomology this has been called abaxile open core.

Split Core.—This is the result of splitting of both endocarp and flesh. Usually such breaks occur at the calyx end, although they may occur at the stem end. Such breaks may reach the surface and result in a passageway into the core. Cases have been found where small breaks became closed, as far as the eye could see, as a result of growth of the surrounding tissue, in the same manner as described in the development of the woolly streaks.

Mouldy Core.—Occasionally an apple is found with a rot developing in the flesh around the core. This is the stage referred to by Carne, Pitman and Elliott (*4*) as "mouldy core"; they consider the presence of organisms not causing a rot as "fungal growth." In the work in Nova Scotia the presence of moulds or discolorations that indicates organisms present has been classed as "mouldy core" by Brittain and Blair (*1*) and Brittain and Eidt (*2*), and this practice is continued because of its acceptance by the growers.

Terms Employed

Some difficulty has been experienced in determining the meaning of certain terms used in describing the calyx end of the apple. The following gives the limits of the terms used in this paper.

1. *Calyx basin.* The depression at the apex of the apple. The sepals divide it from the "calyx tube."

2. *Calyx tube*, sometimes called "Calyx cup." The cavity formed by the union of the bases of the sepals and extending from the sepals to the point of union of pistil and flesh.

3. *Style tube.* A passageway through the centre of the style that connects the core with the calyx tube. This was described by Miss Tetley from the variety Bramley's Seedling.

4. *Open core.* A core with an opening connecting it with the "calyx tube." Includes all breaks in the continuity of the tissue that permit penetration by saprophytic fungi. Replaces "open calyx tube" because it is considered more descriptive and cannot be confused with "open calyx."

5. *Open calyx.* The condition where the sepals do not block the outer entrance to the calyx tube and is contrasted with closed calyx when describing varieties of apples.

Varieties Affected

Table 1 contains a list of varieties that have been personally examined and found affected with mouldy core. There are undoubtedly other varieties which possess this peculiarity but no effort has been made to make a complete survey of the 200 or more varieties available at the Experimental Station, Kentville, N.S.

TABLE 1.—VARIETIES AFFECTED WITH MOULDY CORE IN NOVA SCOTIA

Variety	Chromosome class	Severity of disorder	Comments
Old Gravenstein	Triploid	Severe	Reported by Brittain
Crimson Gravenstein	Triploid	Severe	Reported by Brittain
Banks Gravenstein	Triploid	Severe	Reported by Brittain
Johnson's Gravenstein	Triploid	Severe	Only a few examined
Belle de Boskoop	Triploid	Severe	Reported by Brittain
Bramley's Seedling	Triploid	?	Reported by Brittain
Red Delicious	Diploid	Slight	
Opalescent	Diploid	Slight	Only one large apple observed affected
Stayman Winesap	Diploid	Slight	Reported from U.S.A. by Longyear and Heald
Evangeline	Unknown	Very severe	A local Nova Scotian variety
Ortley (Cleopatra)	Unknown	Severe	Reported from Australia. Probably a diploid.

Object of the Investigation

The main object of the investigation was to find out the cause of mouldy core and although time has not permitted the investigation of all the points raised, a number of interesting facts have been found. The experiments were planned to show the effect on mouldy core of thorough pollination and maximum set, thorough pollination and a light set, thorough pollination and very vigorous growth. Five orchards were studied to secure data under normal conditions. Of these, three were well pollinated and two rather poorly. The suggestion of Brittain and Eidt (*2*) that the triploidy of the varieties affected might have some connection was not supported by finding three known diploid varieties affected. No record of the chromosome number of the variety Ortley was found but the high average number of seeds and high pollen germination strongly indicated that it is diploid. Therefore the fact that Gravenstein is a triploid variety was not considered further.

Experimental Procedure

Experiments in 1933 were carried out in Mr. A. S. Banks' orchard at Waterville, N.S., in a solid block of some 250 trees recently grafted to two red-fruited selections of Gravenstein known as Banks' and Crimson. The variety Crimson Gravenstein was selected for the experiments. One tree was tented and pollinated by using bouquets of Golden Russet bloom and a hive of bees to obtain a maximum set. A second tree had 90% of the blossoms removed and the remaining 500 clusters were hand pollinated using Wagener pollen to obtain a light crop of well pollinated fruit. A third tree whose grafts indicated extreme vigour was hand pollinated to

secure data on the relation of vigour to a full crop. In addition records were obtained from picked, prematurely coloured, and drops from the same orchard to secure data under poor pollinating conditions; from two orchards containing Old Gravensteins at Woodville, one owned by Robert Leslie where the set was moderate and poor pollination might be expected, and one of well-mixed pollinating varieties owned by George McLean, where the set was heavy; also from Old and Crimson Gravensteins on the Experimental Station. The Old Gravensteins were in the Tully orchard which is a block of old trees of many good pollinating varieties and the Crimson Gravensteins were in the main orchard with rows of pollinators adjacent.

Records were kept throughout the season of conditions that might lead to an explanation of cause and factors influencing mouldy core. Apples were tagged on control and experimental trees to obtain the percentage of drop and, with the exception of the grafted tree, the data obtained were in keeping with the results of Brittain and Blair (*1*). The grafted tree was abnormal in its rapid growth, high percentage of abnormal pistils, and very heavy drop in August.

The data obtained in 1933 are not directly comparable in all details with those secured earlier by this department or Brittain and Eidt (*2*). Previously the condition open core meant a visible aperture between calyx tube and core. This year, it was found that an opening might appear closed but brown tissue at the angles of the carpels was an indication that an opening was there through which moulds could enter. For this reason, percentages of open core are higher. Similarly, the percentages of mouldy core are higher because, when cultured, this slightly discoloured tissue, disregarded in 1932, almost invariably gave rise to fungi. The numbers of unfilled seeds were recorded separately but are omitted in this paper because when used it was found that they reduced the correlations between weight and seeds. Brittain and Eidt (*2*) included them.

The Banks orchard had an unusually large number of prematurely coloured fruit, together with a heavy infestation of codling moth and gray-banded leaf roller. The apples attacked by codling moth were rejected because it is a well known fact that such apples colour prematurely and drop early. The impression was obtained that the same might hold true for injuries of the leaf roller type where part of the epidermis is removed. Because of this, insect-injured fruit was rejected, with the exception of two lots. It was necessary to pick 1,599 apples to secure the sample of 1,000 for the control and 767 to secure the sample of 502 for prematurely coloured. The 599 insect injured from the former and the 265 from the latter were examined. The data are presented in Table 2.

TABLE 2.—THE INFLUENCE OF SELECTION ON THE PERCENTAGE MOULDY CORE IN CRIMSON GRAVENSTEINS

Origin	Percentage mouldy core	Average number seeds per apple	
		Healthy	Mouldy
Prematurely coloured	72.7	3.0	2 5
Control	37 4	3.0	2 3
Insect injured from prematurely coloured	60.4	3.1	2 6
Insect injured from control	57.1	3.0	2.5

The percentages of mouldy core in prematurely coloured and insect injured are abnormally high compared with the control and indicate a correlation between them. The reason for the connection between insect injured and mouldy core is not apparent and no attempt is being made to explain it. However, the association complicates the study of the trouble and makes it inadvisable to compare directly orchards with different degrees of pest control.

The Relationship Between Mouldy Core and Pollination

The data from four commercial orchards previously mentioned are presented in Table 3 as indicative of the percentages of mouldy core to be found under ordinary conditions.

TABLE 3.—THE PERCENTAGE MOULDY CORE AND NUMBER OF SEEDS IN PICKED AND PREMATURELY DROPPED APPLES FROM FOUR ORCHARDS

Variety	Orchard	Type of fruit	Percentage of mouldy core	Average number of seeds per apple	
				Healthy	Mouldy
Old Gravenstein	McLean	Picked	10.8	3.3	3.1
		Dropped	47.7	3.7	3.8
Old Gravenstein	Leslie	Picked	23.7	2.5	2.7
		Dropped	64.4	3.4	2.5
Old Gravenstein	Tully	Picked	12.7	3.5	3.7
		Dropped	40.3	3.6	3.8
Crimson Gravenstein	Experimental Station	Picked	11.9	4.2	4.5
		Dropped	26.4	4.5	4.0

The Leslie orchard was the only one that showed signs of inadequate pollination, and the data resemble in many respects those secured from the Banks' orchard (see Table 4). The high percentage of mouldy core and low seed content is quite in keeping with the theory advanced by Brittain and Eidt (*2*). The owner, however, has never considered the premature drop as being of economic importance. The McLean orchard had a very small drop and it was not possible to find the one thousand prematurely dropped apples desired for the records. The Tully orchard had a moderate drop and the Station orchard had a heavy one, although judging from the seed content these orchards were equally as well pollinated as the McLean orchard.

Table 4 presents the data for the different pollination methods.

In Table 4, the figures for "Control" were obtained by taking 100 apples from each of ten trees. Five of these were grafts and five, normal trees. The mouldy core averaged 38.6% on the grafts, and ranged from 32 to 48; on the normal trees 36.2%, and ranged from 22 to 53. The averages obtained from the drops from the experimental trees were obtained from 44 apples for the grafts, 50 for the deflorated and 111 for the tented. The definite association established by Brittain and co-workers between methods of pollination and seed content is evident. It cannot be concluded, however, that adequate pollination controls mouldy core. The

TABLE 4.—THE INFLUENCE OF DIFFERENT METHODS OF POLLINATION ON THE AMOUNT OF MOULDY CORE AND THE NUMBER OF SEED IN PICKED AND DROPPED APPLES. ORCHARD OF A. S. BANKS

Variety	Tree treatment	Method of pollination	Type of fruit	Percentage of mouldy core	Average number of seeds per apple	
					Healthy	Mouldy
Crimson Gravenstein	Tented	Bees and bouquets	Picked	22.2	4.2	4.4
Crimson Gravenstein	Tented	Bees and bouquets	Dropped	53.2	4.2	4.6
Crimson Gravenstein	Deflorated	Hand	Picked	23.3	6.0	6.0
Crimson Gravenstein	Deflorated	Hand	Dropped	34.0	4.2	6.0
Crimson Gravenstein	Grafts	Hand	Picked	38.4	4.7	4.1
Crimson Gravenstein	Grafts	Hand	Dropped	29.3	4.8	5.1
Crimson Gravenstein	Control	Open	Picked	37.4	3.0	2.3
Crimson Gravenstein	Control	Open	Dropped	68.8	2.6	2.9

percentage from the tented tree is within the extremes of mouldy core from the controls. It should be stressed that mouldy core was very slight in most of the apples from the tented tree and undoubtedly many would have been overlooked in 1932.

Most of the data from Tables 3 and 4 have been arranged in Table 5 to show the percentage of mouldy core in different seed content classes. It was felt that such a treatment should show any relationship that existed between seed content and mouldy core.

TABLE 5.—THE RELATION BETWEEN SEED CONTENT AND MOULDY CORE IN APPLES

Variety	Origin	Type of fruit	Per cent of mouldy core in different seed content classes			
			0–2	3–5	6–8	9–12
			%	%	%	%
Crimson Gravenstein—A. S. Banks	Tented	Picked	19.0	21.2	25.4	44.4
	Deflorated	Picked	26.6	23.6	23.2	20.5
	Grafts	Picked	33.0	36.4	41.0	—
	Orchard run	Picked	45.0	32.4	13.5	—
	Orchard run	Dropped	70.9	67.7	58.0	—
	Premature	Picked	75.3	71.0	69.4	—
Old Gravenstein	Orchard run (Leslie)	Picked	22.2	17.2	50.0	—
	Orchard run (Leslie)	Dropped	65.4	63.8	58.1	—
	Orchard run (McLean)	Picked	10.5	6.4	8.7	—
	Orchard run (McLean)	Dropped	44.7	44.1	49.6	—
	Orchard run (Tully)	Picked	10.4	13.3	15.2	17.3
	Orchard run (Tully)	Dropped	34.1	42.4	41.3	—
Mean of seed content classes			42.2	33.2	32.1	25.3

It is at once evident that there is no constant trend of the percentages of mouldy core from the various orchards and treatments. It is apparent from a study of the experiment treatment that factors other than pollination play a part, for the trends are reversed in defloration and grafts. However, the means of the total apples for each class support the theory of a connection between low seed content and mouldy core. It must be concluded, therefore, that in certain orchards there is a definite association between low seed content and mouldy core that does not appear in others and that good pollination tends to reverse this relationship.

The Relationship Between Weight and Mouldy Core

While taking the records of seeds and mouldy core it was noted that the larger apples appeared to have a higher percentage of mouldy core and as a result the rest of the fruit was weighed to the nearest gram. It was found that mouldy core apples averaged 12.2 grams heavier than healthy with a range of from 3 to 17 grams per tree.

The data for weight and mouldy core, arranged in the same manner as for seeds and mouldy core, are presented in Table 6.

TABLE 6.—THE RELATION BETWEEN WEIGHT AND MOULDY CORE IN APPLES

Variety	Origin	Type of fruit	Per cent of mouldy core in different apple weight classes, grams			
			0–70	71–100	101–130	131 and over
			%	%	%	%
Crimson Gravenstein	Tented	Picked	12.8	20.0	30.5	37.7
A. S. Banks	Tented	Dropped	21.9	59.0	88.8	—
	Deflorated	Picked	·	0.0	15.8	26.9
	Grafts	Picked	—	20.0	35.0	41.8
	Orchard run	Picked	0.0	18.7	18.7	32.2
Crimson Gravenstein	Orchard run	Picked	—	2.8	14.0	17.4
Exp. Station	Orchard run	Dropped	—	10.0	20.5	50.0
Old Gravenstein	Orchard run	Picked	1.3	6.2	13.7	23.3
Exp. Station	Orchard run	Dropped	28.6	32.1	45.2	64.3
Mean of apple weight classes			9.7	16.0	20.2	29.6

The classes with the exception of the first and last roughly corresponded to quarter-inch differences in diameter of the apples. It is concluded from Table 6 that mouldy core is associated with size of the fruit.

To find out whether there was any connection between seeds and weight the correlation coefficients have been calculated from the data available from the larger population. It is regretted that weights are not available for apples from all the orchards. Those available are presented in Table 7.

There is a low positive correlation between filled seeds and weight that is significant. This correlation was greatly reduced or insignificant when weight and all seeds were correlated and it was because of this that filled

TABLE 7.—CORRELATION COEFFICIENTS FOR WEIGHT OF APPLE AND NUMBER OF FILLED SEED IN HEALTHY AND MOULDY-CORE APPLES FROM VARIOUS SOURCES

Variety	Origin	Type of apple	Condition of apples	Number of apples	Correlation coefficient
Crimson Gravenstein	Tented	Picked	Healthy	749	0 247 ± 0.023
A. S. Banks	Tented	Picked	Mouldy	214	0 201 ± 0.044
	Tented	Picked	Healthy*	749	0 108 ± 0 024
	Tented	Picked	Mouldy*	214	0 162 ± 0 045
	Hand pollinated	Picked	Healthy	311	0 337 ± 0.034
	Hand pollinated	Picked	Mouldy	123	0.147 ± 0.060
	Control	Picked	Healthy	153	0.294 ± 0 050
Old Gravenstein	Tully orchard	Picked	Healthy	2751	0 363 ± 0 011
		Picked	Mouldy	400	0 368 ± 0 029
		Drops	Healthy	371	0 355 ± 0 031
		Drops	Mouldy	250	0 365 ± 0 037

*Analysis based on all seeds.

seeds were used throughout. The correlations are similar for healthy and mouldy, as shown in the analysis of the data from the Tully orchard. The low correlation for hand pollinated to mouldy is due to the average weight of the grafted tree being 141, and of the deflorated being 153 grams. The healthy fruit was almost identical.

Organisms Present

The results from isolations made in 1933 were similar to those previously obtained and are briefly summarized as follows. The genus *Alternaria* predominated. The cultures differed so much in growth characteristics that eight types could be distinguished. However, the spore sizes were uniform for all and fell within the limits of *Alternaria tenuis* Nees, a common saprophyte. The genus *Fusarium* was also well represented by cultures of ten distinct types. Other genera were represented by a few cultures of *Cladosporium*, *Penicillium*, and unknown sterile forms. Yeasts and bacteria were isolated quite commonly with the various moulds, as would be expected with a visible opening present. The results of the two years' isolations indicate that the organisms associated are chance invaders which thrive according to their adaptability to this particular environment.

Observations of the Calyx End of the Apple

An attempt has been made to ascertain the manner in which an open core originates. Several papers have dealt with the vascular system of the apple, but none has described the development of the calyx region with sufficient detail to serve as a basis for an explanation of the problem. Tetley (*11*) describes the style tube as becoming closed by interlocking of the cells, and this is the view accepted by Brittain and Eidt (*2*) in respect to Gravensteins. During the present studies a style tube has been found in Bramley's Seedling but not in Gravenstein. During the examination of the variety Red Delicious, a few open cores were found that might have originated in the same manner as in Bramley's. These observations

are based on the similarity of the condition in mature apples, and a study of the seasonal development may show otherwise.

A limited study was made of young developing fruit on the only material available which, unfortunately, was on the unsusceptible variety Wagener. Samples of this variety, preserved for another purpose, had been collected at weekly intervals starting with the pink bud stage and ending when the apples were one and a half centimetres in diameter. Freehand sections were made and it has been impossible to demonstrate any opening into the carpels in this material either through the style or where the style unites with the tissue of the young apple. The tissues of the flesh and pistil are continuous in the youngest stages. In apples one and a half centimetres in diameter openings in the tissue are visible near the carpels. Their origin is not known. In mature Wageners, openings at irregular points in the interior of what was originally the style were found. In the variety Stark several apples were sectioned and such openings were not found. A study of this region in varieties affected with open core shows a number of interesting conditions. In Red Delicious and Ortley the growth of the apple frequently causes a pulling apart of the strands of the old style. This also happens in many varieties not affected with mouldy core, such as McIntosh. The difference is that the separation of the strands of the style causes a rupture that reaches the calyx tube in Delicious and Ortley and does not in other varieties.

There is great variation between varieties in the development of the flesh of the apple around the calyx end. In Gravenstein the growth gives rise to a wide basin and a large tube that varies in depth from direct contact with the carpels to being one centimetre away. In Stayman Winesap the apex of the apple is more pointed and the calyx tube is close to or in contact with the carpels. In certain apples of these two varieties there has been little or no development of the tissue that was in direct contact with the style at blossom time and the calyx tube has not been separated from the carpels by the growth of this tissue. In the variety Stark, for example, not affected with open core, the same region has increased until there is often over one centimetre of flesh.

Split core was commonly found in three varieties. In Gravenstein it varied from tiny breaks at the apex of the carpels to cracks that almost divided the apple in half, longitudinally. In Ortley the splits were longitudinal or transverse. In Stayman Winesap they were transverse and occurred most frequently at the base of the carpels. Breaks in the flesh occur in other varieties not affected with open core, such as McIntosh which is subject to hollow core and the pulling apart of the strands of the style.

Excluding Bramley's Seedling and its style tube, open core is considered as arising as a result of rapid or irregular growth during the summer which sets up stresses that cause ruptures in the different tissues. These are in order of decreasing frequency: woolly streak, hollow core, split core, and open core. The type of disorder is dependent on the peculiarity of the variety. The amount of open core may be modified by any of the factors influencing rate of growth and size of fruit, such as set of fruit, vigour of the tree, water supply, fertilizer, etc.

DISCUSSION

Although not presented, the data obtained in 1933 show conclusively the close relationship between mouldy core and open core. A few healthy open core, and a few closed mouldy core fruits were found in McLean's orchard. The other orchards and experiments had very few or no apples in these categories. The study of the organisms present indicates that they are casual invaders by way of the opening and that *Alternaria* and *Fusarium* species thrive because of their adaptability to the peculiar environment of the core of the apple.

The relationship of premature colouring of the fruit to open and mouldy core is not clear because 25 to 40% of the prematurely coloured are free from the trouble. Therefore it seems better to think of the factors that cause premature colouring of the fruit as predisposing it at the same time to open core and mouldy core. Brittain and Blair's work (*1*) proves a very close relationship between pollination as modified by weather and orchard conditions and average seeds per apple. Studying the average seed content of the different classes it is to be noted that no consistent differences are to be found between mouldy core and healthy, between premature coloured and healthy, or between premature drops and picked.

Healthy picked and healthy drops in the Tully orchard had lower average seed contents than the mouldy apples in the same classes, and yet significant differences are reversed in Banks' orchard where the healthy picked had an average of 3 filled seeds and the mouldy, 2.3. It is evident that the average seed content cannot be taken as evidence to support a pollination theory of the origin of mouldy core and premature colouring of the fruit. The data more consistently supports the theory held by Carne, Pittman and Elliott (*5*) that "split core" which may become open core is the result of rapid and irregular growth.

Mouldy core (which follows open core) apples always averaged heavier (larger) than healthy. The largest amounts of mouldy core were found in orchards with a light to medium crop. Even this is not completely supported by the records from individual trees, for the tented tree had 22% mouldy core, which was the same as for one open-pollinated tree in the same orchard. Individual trees vary greatly and it is felt that the high percentage found in the tented tree is the upper limit of mouldy core in a heavy crop. It is evident that the variety Gravenstein is predisposed to open and mouldy core from its growth habits and the constitutional weakness of the calyx end.

When considering the evidence in favour of effective pollination preventing the premature drop associated with mouldy core, we have the tented tree, deflorated tree, McLean's orchard and the Tully orchard with few drops, in support. On the negative we have the recently grafted tree, hand pollinated tree and the Crimson Gravensteins in the mixed orchard of the Experimental Station with many drops where conditions for effective pollination existed. If we use the average number of filled seeds per apple to indicate degree of pollination we have conflicting evidence The group in support of the pollination theory all have a high average seed content (3.7 to 6.0 per cent), but on the negative we have the Experimental Station Crimson Gravenstein with an average of over 4 filled seeds

per apple, which is identical with that of the tented tree, and yet with a drop comparable to Banks' open pollinated with an average close to 3 filled seeds. The average filled seed this year is very high, in many cases as high or higher than total seeds as reported by Brittain and Eidt (*2*). Weather conditions were favourable for pollination but in A. S. Banks' orchard bees were almost totally absent up to and during full bloom of the Gravenstein. Whether this obscures results or not cannot be stated. The general crop and drop bear the same relationship to each other as in 1932.

SUMMARY

1. The percentage of mouldy core in Gravensteins is directly dependent on the percentage open core. The various fungi present are considered chance inhabitants that rarely parasitize their host.

2. Mouldy core apples average heavier than healthy and on any one tree the percentage of mouldy core is higher in the heavier apples.

3. Open core is considered the result of rapid growth at some period during the life history of the apple that causes a break in the tissues of the core that leads to an opening, usually into the calyx tube.

4. The early maturity (premature colouring) of the fruit is closely related to mouldy core and open calyx, but 25 to 40% cannot be explained, as they are free from the trouble.

5. It has not been found possible to correlate average seed content with mouldy core, or premature drop under 1933 conditions.

6. It is shown that faulty pollination cannot be considered the fundamental cause of mouldy core. It is an important factor as it influences the number of apples that set, and the set influences the size to which the individual apples grow.

7. Premature drop is considered as partially correlated with premature colour which indicate early maturity. Early matured apples are 60 to 75% open calyx mouldy core, due, it is considered, to too favourable chances for growth.

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REFERENCES

1. Brittain, W. H. and Blair, Donald S. Studies in interfruitfulness of standard varieties. See, Apple pollination studies in the Annapolis Valley, N.S. Dom. Dept. Agr. Bul. 162. Section 3 : 37-72. 1933.

2. ———— and Eidt, C. C. Seed content, seedling production and fruitfulness in apples. Can. Jour. Res. *9* : 307-333. 1933.

3. Brooks, C., Cooley, J. S. and Fisher, D. F. Diseases of apples in storage. U.S.D.A. Farmers' Bul. 1160. 1930.

4. Carne, W. M., Pittman, H. A. and Elliott, H. G. Notes on certain disorders of Cleopatra apples. Jour. Council Sci. and Indust. Res., Australia. *2* : 49-52. 1929.

5. ——————————. Notes on wastage of non-parasitic origin in stored apples. Jour. Council Sci. and Indust. Res., Australia. *3* : 167-203. 1930.

6. Cook, Mel. T. and Martin, G. W The Jonathan spot rot. Phytopath. *3* : 119-120. 1913.

7. Heald, F D. Mouldy core of Stayman Winesap (Abst.) Phytopath. *11* : 105. 1921.

8. Longyear, B. O. A new apple rot. Col. Agr. Exp. Sta. Bul. 105. 1905.

9. O'Gara, P. S. Studies on water core of apples. Phytopath. *3* : 121-128. 1931.

10. Sorauer, P. Manual of Plant Diseases. Translation by Frances Dorrance. Vol. 1. 1922.

11. Tetley, Ursula. The morphology and cytology of the apple fruit with special reference to the Bramley's seedling variety. Jour. Pomology Hort. Sci. *9* : 278-297. 1931.

Résumé

Moisissure du cœur dans les pommes Gravenstein. K. A. Harrison, Laboratoire fédéral de pathologie végétale, Kentville, N.-E.

Le pourcentage de cœur moisi dans les Gravensteins dépend directement du pourcentage de calices ouverts. On considère que les différents champignons présents sont des habitants de hasard, qui attaquent rarement leur hôte. Les pommes à cœur moisi sont en moyenne plus lourdes que les pommes saines et sur tous les arbres le pourcentage de cœur moisi est plus considérable dans les pommes lourdes que dans les autres. On considère que le cœur ouvert est le résultat de la végétation rapide à une certaine période pendant le cycle évolutif de la pomme qui cause une rupture dans les tissus du cœur, conduisant à une ouverture, généralement dans le tube du calice. La maturité précoce (coloration prématurée) des fruits se rattache intimement au cœur moisi ainsi qu'au calice ouvert, mais de 25 à 40 pour cent ne peuvent s'expliquer, car ils n'ont pas cette infection. On n'a constaté aucune relation entre la proportion moyenne de pépins avec le cœur moisi, ou la chute prématurée des fruits dans les conditions de 1933. Il a été démontré que la pollinisation défectueuse ne peut être considérée comme la cause fondamentale du cœur moisi. C'est un facteur important car il influence le nombre de pommes qui nouent et la nouaison influence la grosseur que les différentes pommes peuvent atteindre. On considère que la chute prématurée a certains rapports avec la couleur prématurée qui indique une maturité hâtive. De 60 à 75 pour cent des pommes mûries prématurément ont un cœur moisi et un calice ouvert dont la cause est due, croit-on, à des chances de végétation trop favorables.

COLLETOTRICHUM GRAMINICOLUM (CES.) WILS. AS A PARASITE OF THE STEM AND ROOT TISSUES OF *AVENA SATIVA*[1]

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During recent years, oats *(Avena sativa)*, in the Edmonton district, have been observed to suffer from a rather serious type of root rot, the effects of which are most evident just prior to elaboration of the adventitious root system. This report will provide evidence, secured since the preliminary note (*4*), that *Colletotrichum graminicolum* (Ces.) Wils. may cause the symptoms referred to.

Symptoms

Gross symptoms of the disease in the field appear about six to eight weeks after seeding, before the adventitious root system can provide food. In severe cases, rather well defined areas occur, where the plants are distinctly stunted (Figure 1A). Such areas, however, are not necessarily those in which stunting, caused by malnutrition of the plants, are found, although indications are that both disease and malnutrition may appear together, the effects of one apparently intensifying those of the other.

The first and second leaves of affected young plants are more or less brown, becoming reddish brown at first and finally dying from the tip toward the base. Chlorotic areas and disease lesions are normally absent. In Figure 1B are shown affected oat plants which are typically thin in root, stem and general growth habit. These were grown in the greenhouse in natural field soil from an infested area. In severe cases the emergence of the panicle is retarded and definitely reduced in size, and the numbers of tillers is seldom more than one. Although infection at the base of the panicle has been observed in the field (Figure 2, A and B), and also produced experimentally, it is uncommon. However, infection of any part of the stem may, under moist conditions, become heavy late in the season. Usually this is greater below the nodes than above them, apparently because these areas are exposed. The seminal roots and the first internode of affected plants early become thin, poorly developed, and straw coloured. In general, the affected parts do not become dark as when roots of cereals are infected by *Ophiobolus graminis* or *Helminthosporium* sp. and other common root-rotting organisms. The shrinkage of the seedling axis from the scutellar node to the coleoptilar or second node, is distinct and typical. Although adventitious roots may be attacked as they emerge, there is a marked tendency for these to escape serious injury. When these roots are established the plant begins to recover.

Soon after the tendency toward recovery is evident, black, stromatic bodies, in the beginning loose and very small, later becoming more solid, and in shape varying from round to long oval, appear on the rhizome (Figure 2C), and also on the culm at ground level. These bodies persist and are viable at least until May the following spring. Careful, although

[1] Contribution No 420 from the Division of Botany, Experimental Farms Branch, Department of Agriculture, Ottawa, Canada, co-operating with the University of Alberta. Presented at the fourth annual meeting of the Canadian Phytopathological Society held at Macdonald College, P.Q., June 26 and 27, 1934.

[2] Plant Pathologist in Charge.

not exhaustive, search has so far failed to reveal spores produced on these bodies borne below ground level.

As far as could be determined, the grains from plants, the culms of which bore rather heavy infestation on the higher nodes and stems, were not affected, although it would seem that such attack, if early and severe, might lead to some shrinkage in yield. However, indications were that severe infection of the crown of oats at soil level hastens maturity of both plant and grain. The main damage seems to arise from injury to the seminal roots, and to the seedling axis below the coronal node during the seedling stage, which takes form in reduced size of panicle, number of tillers, and stunting mentioned earlier.

Prevalence

This disease now appears to be prevalent in the black soil area immediately north and east of Edmonton. It has also been observed in the Peace River district, and at other points in the black soil area tributary to Edmonton, and southward for nearly 200 miles. Bodies, typical of *C. graminicolum*, on the base of mature wheat plants collected by Dr. P. M. Simmonds at Indian Head, Saskatchewan, were identified. With regard to the differential effect of previous crops on the disease, no definite evidence is available, but it is interesting to note that several of the most severe cases have followed two or more crops of oats.

Historical

In 1909 Selby and Manns (*6*) of Ohio published a study on a new anthracnose disease of cereals and grasses, and described the causal fungus as *Colletotrichum cereale* Manns, parasitic on the roots, culms, blades and spikes of certain cereals, including *Triticum vulgare, Avena sativa, Hordeum vulgare, Triticum spelta, Dactylus glomerata, Phleum pratense, Poa pratensis,* and *Bromus secalinus*. Apparently the infection of the root and basal portion of the hosts mentioned was not determined by experiment, but based on field observations. In view of the possible effect of other pathogenic soil-inhabiting fungi, such as *Fusarium* spp. and *Helminthosporium* spp., it would seem unsafe to conclude from the mere presence of acervuli that the root rot observed was caused by *C. graminicolum*. However, their experimental results leave no doubt that this fungus is pathogenic to the above-ground parts of a number of the Gramineae.

In Canada, this species has been reported (*1*) on certain hosts, including Poa, Beckmania, wheat and oats, but apparently it has not been considered an important root-rotting organism.

The Pathogen

A number of isolations were made from the young seminal roots, the seedling axis below the crown, the crown, and also from acervuli, or sclerotoid bodies, produced on parts in the field. A *Colletotrichum* sp. was a frequent isolate. Two of these isolates from the first internode were kindly identified as *Colletotrichum graminicolum* (Ces.) Wils. (*C. cereale* Manns) by Mr. S. F. Ashby, Mycologist, Imperial Mycological Institute, Kew, England.

EXPERIMENTAL RESULTS

Pathogenicity

Tests were made in open pot culture, using one of the identified isolates, increased on a sterilized mixture of soil and oat hulls. This was mixed with sterilized soil, and grains of oats, of both Victory and Banner varieties, surface disinfected in mercuric chloride, were planted. The plants from certain pots were taken up at intervals of 10 days, examined for disease, and tissue reserved for microscopic examination.

There was no doubt that the culture used had severely disabled the seminal roots and injured the first internode of the young oat plants in a way corresponding to the gross symptoms observed in the field. That is to say, these seminal roots were more or less dead and stunted, and usually straw-coloured, while the rhizome was definitely shrunken from the scutellar node to the coronal node. As soon as the adventitious roots were established, the plants tended to revive, and many became normal under the conditions of the test (soil temperature 19°–21° C.). In pot culture, faint beginnings of acervuli appeared about 40 days after seeding, and in 60 days on the internodes and the crown at or below ground level. Indications were that the seminal roots are particularly susceptible, as is also the first internode. As a rule, the adventitious roots were not severely injured.

Pathological Histology

Portions of the seminal and adventitious roots of the first and second internode and of the crown area were fixed for 24 hours in Bouin's fluid, to which one gram of urea was added for each 100 cc., washed in four changes of 30% alcohol, and dehydrated by the N-butyl alcohol method, then embedded in paraffin containing 0.001% crude rubber. The sections, cut 15 μ in thickness, were stained in 1% aqueous safranin for one minute, rinsed in tap water, then placed in picro-aniline blue, as prepared by Cartwright (*2*) for 20 minutes, rinsed, and dehydrated in 95% and absolute alcohol, followed by clove oil, then mounted in balsam.

Seminal roots

The seminal roots of affected plants were extensively invaded soon after they were produced. The cells of the cortex and endodermis were collapsed and the invading hyphae more or less completely disintegrated. The cells of the pericycle and central stele, although ramified, retained their form, and the hyphae appeared to persist. In fact a clear cut case of disintegration of hyphae was not observed in either the pericycle or the stele. The cells of the pericycle were obviously and characteristically plugged by hyphae arranged parallel to the main axis of the root. The stele, although penetrated much more slowly than the cortex is, may be extensively ramified and more or less plugged. The invasion of a seminal root 10 days old by *C. graminicolum* is illustrated in Figure 3A. With young seminal roots so invaded and obviously incapacitated in so far as their absorbing area is concerned, and with the vessels only partly functional, the observed injury reflected by such young seedling plants is not surprising.

Figure 1 *Avena sativa* attacked by *Colletotrichum graminicolum*. A. Typical effect of injury to root and rhizome in field. Left, seedling; right, post seedling stage B. Left, thin appearance of plants reproduced in greenhouse in infested soil from field; and right, normal check plants C Typical sclerotoid bodies on plants 60 days old, grown in sterilized soil artificially infested

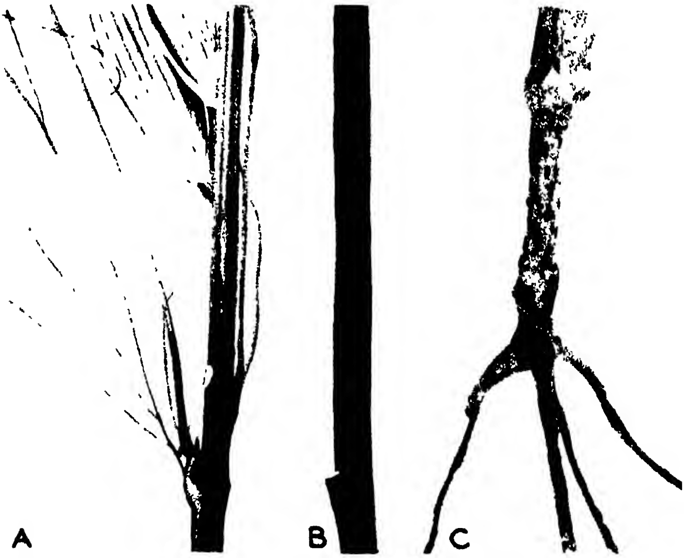

Figure 2 Field specimens of mature oat plants attacked by *Colletotrichum graminicolum*. A Infection of panicle and peduncle, exterior view B. Sclerotoid bodies within cavity of stem. C. Sclerotoid bodies on rhizome and base of culm.

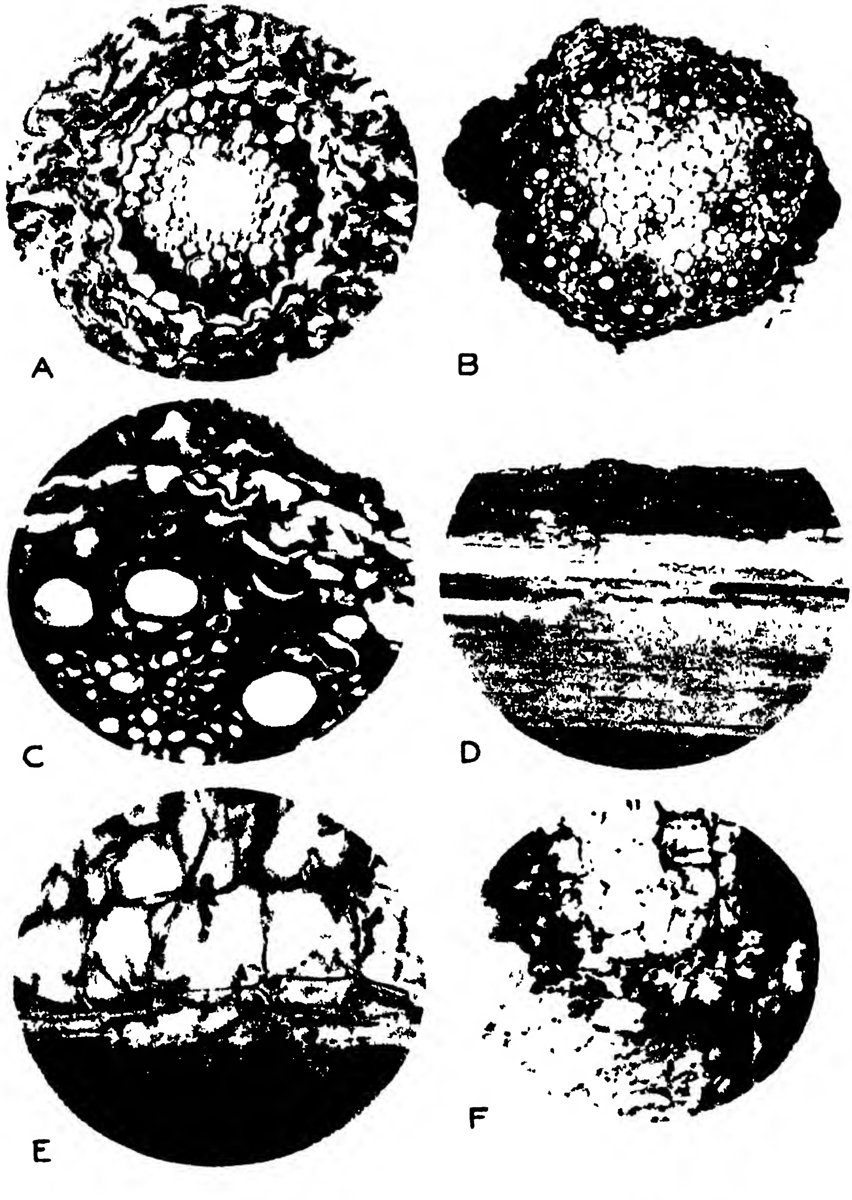

FIGURE 3 *Colletotrichum graminicolum* in tissue of *Avena sativa* grown in sterilized soil artificially infested. All tissue, excepting that of A, is 60 days old. A. Seminal root of seedling plant 9 days old Note typical collapse of cortex and endodermis, with attendant disintegration of hyphae, also the extensive development of large persisting hyphae in the pericycle, and the beginning of invasion of the central stele. B. A cross section of first internode extensively ramified by hyphae and typical sclerotoid bodies on periphery C. High magnification of a part of vascular bundle in B. showing collapsed cortex and extensive penetration and plugging of all cells of bundle, excepting the large vessels. D. A tangential long section of rhizome, with sclerotoid bodies on periphery, and sclerotoid and non-sclerotoid mycelium lengthwise of cells. E. Pith tissue of rhizome extensively penetrated. F. A long section through the hollow central cavity of stem immediately above crown node. Note large thick walled hyphae above and extensive penetration of tissue below.

The rhizome

The first internode of the rhizome was, as a rule, easily and extensively invaded (Figure 3, B, C and D), but probably not as quickly or as completely as the seminal roots were. In severe and early cases there was complete collapse of the cortex, accompanied by disintegration of the hyphae. However, penetration of the cortex and epidermal cells of the older tissue is slower than it is in young tissue, and both cells and hyphae tend to remain intact longer. The vascular bundles were often extensively penetrated, but, as a rule, this tissue offered considerable resistance. In the pith cells (Figure 3E) the hyphae developed profusely, and did not disintegrate readily.

Coronal node

From certain rows of infected cells located just below the cortex of the rhizome, the hyphae passed the coronal node, and thence up the culm, and also into the central cavity of the stem immediately above the coronal node, where the mycelium developed vigorously (Figure 3F), and frequently extended rather deeply into the adjacent functional tissue. Infection of the latter cavity was sometimes effected directly through the coronal node, the hyphae passing by way of the softer tissue. However, due to the resistance offered by the vascular strands of this area, progress was slow.

Adventitious roots

In general, the adventitious roots below ground level escaped serious injury, although there were individual cases in both greenhouse and field material where *C. graminicolum* entered deeply with effect. Penetration was usually deeper in the angle made by the root with the crown on the superior side than it was below. Root and also shoot primordia emerging from invaded areas of the crown were frequently damaged. In these roots, as in the seminal roots and rhizome, the hyphae tend to mass in certain continuous rows of cells just below the cortex. Acervuli seldom formed on the surface of the secondary roots below ground, but commonly did so when they were exposed.

Stem

Acervuli devlop most conspicuously on the lower part of the culm, especially on the exposed area just below the node, which is unprotected by the leaf sheath. These bodies break through in the depressions bearing the stomata. In certain cells just below the hypoderm the fungus may pass some distance up the culm, usually plugging them or forming extensive sclerotoid masses near the surface. The conducting tissue of a stem approaching maturity, although often penetrated extensively, offers considerable resistance to radial penetration. However, the hyphae soon reach the central cavity of the stem. This is usually between the large vascular bundles, where the hypoderm band is thinnest and the ground tissue widest. Bodies, which are apparently identical to those which occur on the exterior surface, soon form. Apparently these bodies within the stem cavity bear spores very rarely, if at all, since none were observed in the many specimens examined.

Penetration phenomena

The hyphae of *C. graminicolum* vary greatly in width, and in thickness of the cell wall, as do the hyphae of several well known plant pathogens when in the tissue. However, its general appearance and behaviour differ

sufficiently from that of *O. graminis*, *H. sativum* and *Fusarium* sp. for its identification. One outstanding feature is the extensive packing of the cells in certain areas with more or less sclerotoid mycelium (Figure 3D).

The invading hyphae may be very small threads, or very large and swollen with protoplasm. On penetrating a cell of the epidermis or cortex, a hypha commonly swells to fill a large part of the cell, and extends close to the wall, pushing the contents aside, without causing apparent injury. This behaviour was quite marked in the long epidermal cells. On reaching the end wall of the cell the hypha may pass through it, or curve back to the opposite end, where it again turns, and finally fills the cell with two or more strands. Later, before the cell is killed, these strands may or may not become closely septate, with thick walls, and persist. Again, large hyphae were commonly observed to pass without apparent difficulty through the end walls of several long cells in a row. The thin cells of the cortex of seminal roots, and those of the first and second internode of the rhizome, are penetrated rather easily and freely. Progress of the hyphae in a radial direction is definitely hindered by the sterome and vascular elements, and particularly by the large vessels. However, even these large vessels are entered, but apparently not plugged. There is a distinct tendency for the hyphae to plug sterome cells.

Leach (*3*), studying the behaviour of *C. lindemuthianum* in the tissue of *Phaseolus vulgaris*, observed two kinds of hyphae, namely large primary, which were confined to relatively few cells, and which were compatible with the cytoplasm and nucleus for some time; and secondary or smaller hyphae, which were derived from the primary form and which passed through the tissue freely and rapidly in all directions. He states: "It is quite evident that the difference in character of the primary and secondary mycelium are due to the differences in resistance offered by the cell walls.", which, he adds "depends largely on the age of the tissue." In the present study both large and small hyphae were observed, but whether this difference was due to age of tissue or to the kind and amount of food, or to the softening of the tissue by enzymes elaborated by the primary mycelium was not determined.

Habitat

Experimental results leave no doubt that *C. graminicolum* is a typical soil-inhabiting fungus. Sclerotoid bodies of *C. graminicolum* were observed on the stubble of wheat and of oats plowed under one and two seasons previously, and the fungus isolated therefrom. The possible relation of this as a source of infection to subsequent crops was not determined. However, tests made in open pot culture, and also pure culture, indicated that the isolate of *C. graminicolum*, used in these experiments, does not attack wheat, barley or flax. This suggests the possibility of races of *C. graminicolum* specific to oats, as well as to wheat. Varietal differences in resistance and the host range were not studied.

DISCUSSION

Since the results of this study are based on the performance of a single isolate of *C. graminicolum* in open pot culture, and, therefore, no account was taken of possible physiologic forms, too definite conclusions cannot be

drawn regarding the pathogenicity of this fungus to oat plants under field conditions. Moreover, in either field or artificial pot culture the association effects (*5*) of other soil micro-organisms, undoubtedly play an important role in the development of the disease. However, under the conditions of the test, fairly typical symptoms of the disease, as it appears in the field, were reproduced in the greenhouse. Also, microscopic studies on field and greenhouse material gave unmistakable evidence that *C. graminicolum* could cause definite injury to seedling plants, and to some extent injure more mature ones.

Apparently the cortex of the young seminal roots, and that of the stem between the scutellar and crown nodes, is, of all tissue, most easily and severely affected. Indeed, with the exception of a transient compatibility of host and pathogen, there is complete and early collapse of the cells of the cortex and endodermis with attendant disintegration of the invading hyphae. In general, penetration of all parenchymatous cells is free and relatively easy, especially those with thinner cells, which includes the pith. While some resistance is offered by the sterome and the elements of the vascular bundles, all are penetrated, and, with the exception of the large vessels, are, as a rule, plugged. In both cases the cells remain apparently intact, and the hyphae do not disintegrate, which interesting behaviour is in striking contrast to that which occurs in the cortex, and for which no satisfactory explanation seems available. Thus, on one hand there is the definite, although transient, compatibility between hyphae and host cells when the cortex is first penetrated, followed by collapse of the cells and disappearance of the hyphae, and, on the other hand, the case where the cells apparently are not injured and do not collapse or the hyphae disintegrate. Leach (*3*), in a study of the parasitism of *C. lindemuthianum* on *Phaseolus vulgaris*, states: "In the early stages of normal infection of a susceptible host, *C. lindemuthianum* obtains its nourishment from the living host protoplast.", and observes that in the more resistant tissue the mycelium disintegrates, killing the host protoplast, and staining the cell wall and its contents. He interprets the phenomenon on a nutritional basis, the hyphae being destroyed by autolysis, induced by starvation. If the foregoing theory also applies to the behaviour of *C. graminicolum* in the cortex of *A. sativa*, may one conclude that the vascular and mechanical elements, which are more resistant to penetration, were able to supply sufficient food to prevent autolysis? Hence, in this case it would be conceivable that the antecedents for hyphal lysis occur at least more readily in tissue, the cells of which have functional nuclei and cytoplasm, than in those without.

With regard to the disease as it appears on seedling plants under field conditions, the evidence secured by this study indicated that the early browning of the roots, and stunting, mentioned, is caused mainly, if not wholly, by the practical destruction of the seminal roots, and severe injury of that part of the stem below ground level. On the other hand, the tendency toward subsequent recovery of such plants undoubtedly is explained by the fact that it is coincident with the development of effective adventitious roots, which, as a rule, are not severely penetrated.

ACKNOWLEDGMENT

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REFERENCES

1. BISBY, G. R., A. H. R. BULLER and JOHN DEARNESS. The Fungi of Manitoba. Longmans, Green and Co., London. 194 pp. 1929.
2. CARTWRIGHT, K. ST. G. A satisfactory method of staining fungal mycelium in wood sections. Ann. Bot. *43* : 412-413. 1929.
3. LEACH, J. G. The parasitism of *Colletotrichum lindemuthianum*. Univ. of Minn. Agric. Exp. Sta. Tech. Bul. 14. March, 1923.
4. SANFORD, G. B. A preliminary note on an unreported rootrot of oats. Sci. Agric. *14* : 50-51. 1933.
5. ——————, and W. C. BROADFOOT. Studies of the effects of other soil-inhabiting micro-organisms on the virulence of *Ophiobolus graminis* Sacc. Sci. Agric. *11* : 512-528. 1931.
6. SELBY, A. D., and THOS. F. MANNS. Studies in diseases of cereals and grasses. Ohio Agric. Exp. Sta. Bul. 203. April, 1909.

Résumé

***Colletotrichum graminicolum* (Ces.) Wils. Parasite des tissus de la tige et de la racine de *Avena sativa*. G. B. Sanford, Laboratoire fédéral de pathologie végétale, Edmonton, Alberta.**

Les observations qui ont été faites en plein air, de même que les études conduites en serre et au laboratoire, ont démontré que *Colletotrichum graminicolum* peut créer une grave infection parasitaire des racines séminales et des internodes de la tige au-dessous du collet de plants de l'avoine ordinaire, et causer ainsi différents degrés de rabougrissement et de détérioration, et réduire le nombre des talles et la dimension de la panicule. En général, les plants attaqués tendent à se remettre après que les racines adventices sont établies. L'historique pathologique des racines séminales, du rhizome, du node coronal, des racines adventices et de la tige est décrit ainsi que les phénomènes de pénétration. La culture employée n'a pas attaqué la base ni les racines du blé, de l'orge ou du lin, quoique la présence de cette espèce ait été constatée sur le blé.

STUDIES ON THE CONTROL OF ROOT-ROT DISEASES OF CEREALS CAUSED BY *FUSARIUM CULMORUM* (W.G. SM.) SACC. AND *HELMINTHOSPORIUM SATIVUM* P., K., AND B.

II. PATHOGENICITY OF *HELMINTHOSPORIUM SATIVUM* AS INFLUENCED BY *CEPHALOTHECIUM ROSEUM* CORDA IN GREENHOUSE POT TESTS[1]

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INTRODUCTION

Numerous studies have been made on the association of micro-organisms, not only culture but also in the soil. Experiments to determine the effects of certain soil-inhabiting micro-organisms on the development of diseases caused by fungal pathogens are reported by Johnson (*12*), Endô (*4*), Bamberg (*1*), Weindling (*21*), and others. The results have indicated that many plant diseases caused by soil-borne fungi are influenced by associated organisms to a significant degree, not only as to retardation, but also as to acceleration, of disease processes. The importance of investigations on the effects of known mixtures in comparison with the effect of individual organisms alone in their relation to plant disease has been adequately discussed by Fawcett (*5*), who gives a complete review of the literature upon the subject.

During the past few years considerable attention has been given to the relation of biological antagonism to infection of cereals by root-rot fungi. Henry (*11*) and Sanford and Broadfoot (*19*) found that the microflora of the soil had a marked inhibitive action on the development of root-rot diseases of wheat caused by *Ophiobolus graminis* Sacc. and *Helminthosporium sativum* P., K., and B. In a study of fungi isolated from Manitoba soil Bisby, James and Timonin (*2*) found that *Trichoderma lignorum* (Tode) Harz plays an important part in suppressing the virulence of *Fusarium culmorum* (W.G. Sm.) Sacc. and *Helminthosporium sativum* on wheat. Factors affecting the pathogenicity of cereal root-rot fungi, and the importance of the factor of biological antagonism in the cereal root-rot problem have been discussed by Garrett (*8*). The present paper gives the results of experiments designed to determine the effect of *Cephalothecium roseum* Corda on the pathogenicity of *Helminthosporium sativum*, and gives a detailed account of the methods employed in pot-culture studies with cereal root-rot fungi under greenhouse conditions.

EXPERIMENTAL METHODS

The difficulty of controlling the soil environment in greenhouse pot-culture tests with cereal root-rot fungi is generally recognized. Garrett (*8*) examined the available published work on the effect of soil temperature and moisture upon infection by cereal root-rot fungi and found that in many cases the influence of these factors upon infection varied in an unaccountable manner. The absence of uniformity in the results was

[1] Contribution No. 412 from the Division of Botany, Experimental Farms Branch, Department of Agriculture, Ottawa, Ontario, Canada. Presented at the fourth annual meeting of the Canadian Phytopathological Society held at Macdonald College, P.Q., June 26 and 27, 1934.

[2] Plant Pathologist.

[3] Assistant Plant Pathologist.

attributed by him to be due, in part at least, to the operation of the factor of biological antagonism. Although the importance of this factor in diseases caused by soil-borne fungi can not be over-looked, it would seem, however, that, in attempting to explain the numerous contradictions in the earlier work, consideration must be given to the differences in experimental procedure and the method of recording disease data used by different workers.

Previous experience with numerous pot-culture experiments emphasized the importance, if reliable and reproducible results are to be expected, of controlling in a satisfactory manner the conditions making up the soil environment and of standardizing as far as possible the method of recording the degree of infection caused by cereal root-rot fungi. In other words, experience has led to the adoption of more scientific methods in conducting greenhouse experiments. The methods used in pot tests with cereal root-rot fungi are given in considerable detail in this paper.

Type and Treatment of Soil

The importance of soil type in experiments with soil-borne pathogens is demonstrated by the studies of Garrett (*9*), Henry (*11*), and Moritz (*17*). In the present study a uniform mixture of soil consisting of ⅔ fine clay loam and ⅓ sand was used. The soil was placed in 6-inch flower pots and steam-sterilized for 4 hours at 15 pounds pressure. Immediately after sterilization the fungus to be tested was added to the soil. The subsequent treatment of the soil was such as to prevent its reverting to the non-sterile condition.

Kind of Inoculum and Method of Infesting Soil

Inocula were prepared by growing the fungi on a finely-ground, oat-hull medium. This medium, when completely over-grown with sporulating mycelium of the fungus, was thoroughly mixed with the sterile soil, one part of inoculum to 100 parts of soil by weight. All soil for a given experiment was prepared at the same time.

Soil Temperature and Moisture

At the commencement of an experiment each pot of soil was adjusted to 55% of its total moisture-holding capacity and weighed. This moisture content was maintained by weighing the pots at 2-day intervals and adding sterile water to restore to original weight. A greenhouse furnished with temperature-control apparatus was used for the experiments. During the course of any given trial the soil temperature was controlled within the range 22° to 25° C., while the range of air temperature was from 20° to 28° C.

Seed and Seed Treatment

Five varieties of wheat were used in the present study: Marquis, Mindum, Marquis × Pentad Strain 729, Marquis × Pentad Strain 726 and H-44-24 × Reward Strain 716. The seed was obtained from pure line material and hand-selected for size and plumpness. Each lot of seed was surface-sterilized by rinsing in 80% alcohol, then soaking in a solution of mercuric chloride (1 : 1000) for 3 minutes, rinsing again in 80% alcohol and afterwards thoroughly washing in sterile water. The results of adequate germination tests established that from 96 to 100% of the surface-sterilized seeds were viable.

The seed was sown immediately after sterilization. By means of a small sterile tube 25 holes were made uniformly at a depth of one inch

below the surface in each pot of soil. A single seed was planted in each hole and covered by a light packing of the surface layer. The soil was only slightly disturbed, and the possibility of foreign organisms entering the experimental soils was markedly reduced by this procedure. In order to allow the fungi to become well established in the soil to which they were added, three days were allowed to elapse before planting of the seed.

Recording the Amount of Disease

Accurate measurement of the intensity of infection is essential in studying cereal root-rot fungi. If the results are to be reliable and reproducible the amount of disease must be accurately recorded in a convenient and simple form. The work of Jones, McKinney and Fellows (*13*) on potato scab, and of McKinney (*16*) on a *Helminthosporium* disease of wheat, has demonstrated that it is not sufficiently adequate to use alone either the number of individual plants infected or the degree of infection as the index of the amount of disease. McKinney (*16*) expressed the extent of disease caused by *H. sativum* as an infection rating which took into account the percentage of the total number of plants infected as well as the degree of infection. A modification of McKinney's method seemed well adapted for the investigation of factors influencing the pathogenicity of cereal root-rot fungi, and is used in the present study. The infection classes with their respective numerical ratings are shown in Figure 1.

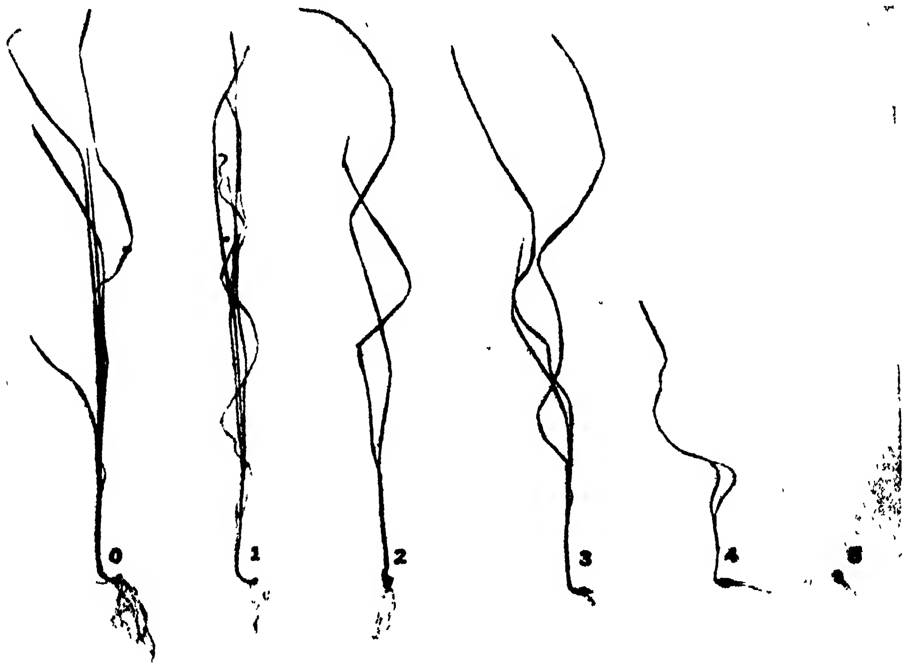

FIGURE 1—Reward wheat seedlings showing infection classes and numerical ratings used in measuring the amount of infection caused by *Helminthosporium sativum* in pot tests. Classes: (0) Healthy, no infection. (1) Small lesions on roots and base of culm. (2) Distinct lesions on base of culm, sheath and roots. (3) Base of culm and root system rotted and markedly reduced. (4) Severe rotting of roots and basal part of plant, plant severely stunted. (5) Seed fails to germinate or plumule and root system rotted or completely destroyed.

In pot tests with cereal root-rot fungi it was considered that any other index of disease intensity, to be of value, must bear relation to the disease rating. In order to determine suitable criteria for measuring the intensity of root rot of wheat caused by species of *Helminthosporium* and *Fusarium* a statistical study was made of the data from properly controlled pot tests. The results clearly established that there was a significant negative correlation between the amount of disease, as expressed by the disease rating, and the total dry weight of plants, while no such association existed between total length of plants and disease rating. In the present study the dry weight of plants was used as an index in determining the comparative effects of *C. roseum* on the pathogenicity of *H. sativum*.

Analysis of Data

The results of previous pot-culture studies on factors influencing the pathogenicity of cereal root-rot fungi have demonstrated that differences in pathogenicity may easily be of small magnitude and require data of a relatively high order of precision for their establishment. Consequently, in order to insure that the observed differences indicated, within the limits of experimental error, the effects of the applied treatments or organisms, the experiment was properly arranged and adequately replicated. The disease rating and dry weight data were treated statistically by the "Analysis of Variance" and "*Z*" test. It is not possible here to illustrate these methods in detail and reference should be made to Fisher (*6*), Fisher and Wishart (*7*) and Goulden (*10*).

THE PATHOGENCITY OF *HELMINTHOSPORIUM SATIVUM* AS INFLUENCED BY *CEPHALOTHECIUM ROSEUM*

In earlier preliminary studies on root-rot and foot-rot diseases of cereals in Manitoba, *Cephalothecium roseum* Corda was frequently isolated from cereal plants grown in soil artificially infested with species of *Fusarium* and *Helminthosporium*. It was observed that the virulence of the root-rot pathogens was markedly reduced in the presence of *C. roseum*. These results suggested further experiments to determine the real effect of *C. roseum* on the virulence of *H. sativum*.

Pot-culture tests were made to study the pathogenicity of *H. sativum* alone, and in association with *C. roseum*. The methods of soil management and infestation, planting of the seed, harvesting of the plants, and recording and analyzing the experimental data used have already been described in the previous section.

The particular pathogen investigation was a fast-growing strain of *Helminthosporium sativum* P., K., and B. which was originally isolated in 1932 from diseased roots of wheat. The pathogenicity of this fungus on wheat, oats, barley and rye was established by numerous greenhouse pot tests. The strain of *Cephalothecium roseum* used was isolated in 1933 from a surface sample of Manitoba soil.

Wheat plants were grown in each of the following types of soil:—

(1) Sterile soil infested with *H. sativum*.

(2) Sterile soil infested with *C. roseum*.

(3) Sterile soil infested with *H. sativum* and *C. roseum*—the amount of oat-hull inoculum of each fungus being one-half that used in (1) and (2).

(4) Sterile soil infested with *H. sativum* and *C. roseum*—the amount of inoculum of each fungus being the same as that used in (1) and (2).

(5) Sterile soil plus oat-hull medium (Control B).

(6) Sterile soil alone (Control A).

The pathogenic capabilities of the fungi separately, and in association, were determined on five varieties of wheat. One hundred surface-sterilized seeds of each variety were planted in four pots of each type of infested and uninfested soil. Thus there were 20 pots of each soil type, the complete experiment consisting of 120 pots. In order to take care of place effect the pots were properly randomized on the greenhouse bench. All soil was prepared, sterilized and infested, and the seed planted at the same time, so that all conditions, with the exception of the soil fungi, were comparable. Uniform conditions of soil moisture and temperature were maintained during the period of the experiment. The experiment was replicated three times.

Germination counts were made 15 days after planting. It was observed that the germination of seed of all wheat varieties was markedly reduced in pots of sterile soil to which *H. sativum* had been added, while the presence of *C. roseum* alone in sterile soil did not affect germination. The germination results with sterile soil, sterile soil plus oat-hull medium, and sterile soil infested with *C. roseum* were almost identical. It was observed, however, that the detrimental effect of *H. sativum* on seed germination was decidedly reduced in the presence of *C. roseum*, the percentage of germination being considerably higher in soil where *H. sativum* was associated with *C. roseum*.

At the end of the experimental period (36 days) the plants were washed free of soil, examined, and the degree of root-rot infection was recorded according to the methods described above. The plants were air-dried and the total dry weight of each variety in each soil series was obtained. A general examination of the disease rating and dry weight results indicates a real difference in the pathogenicity of *H. sativum* on wheat. In order to verify the results a thorough examination of the data was made. Table 1 gives the results of the complete analysis of variance for disease rating and total dry weight of plants.

The significance of the results is assessed by the Z test (Fisher (*6*)), in which the variance due to any known cause is compared with the variance due to error. The values of Z in Table 1 greatly exceed the 1%

TABLE 1.—ANALYSIS OF VARIANCE: DISEASE RATING AND DRY WEIGHT OF PLANTS

Disease rating

	Degrees of freedom	Sum of squares	Mean square	Z	1 per cent point
Experiments	3	1580.54	526.85		
Varieties	4	1403.11	350.78	0.5594	0.6325[1]
Soil treatments	5	134655.54	26931.11	2.7183	0.5871
Soil treatments × varieties	20	1371.60	65.58		
Error	87	9970.56	114.60		
Total	119	148981.35			

TABLE 1.—ANALYSIS OF VARIANCE DISEASE RATING AND DRY WEIGHT OF PLANTS—*Concluded*

Dry weight of plants

	Degrees of freedom	Sum of squares	Mean square	Z	1 per cent point
Experiments	1	12.24	12.24		
Varieties	4	46.13	11.53	1.2980	0.6987
Soil treatments	5	101.40	20.28	1.5803	0.6576
Soil treatments × varieties	20	6.22	0.31		
Error	29	25.06	0.86		
Total	59	191.05			

[1] 5% significant level required for $n_1=4$, $n_2=87=0.4535$.

points and indicate that a high degree of significance can be attached to the differences between the pathogenicity of *H. sativum* in the various soil series. Differences between varieties of wheat are also significant. With the establishment of significant differences in pathogenicity and varieties, a detailed examination of the results was made. The standard errors of the means of soil treatments and varieties are given in Table 2. This table presents a complete summary of the results of the experiment.

TABLE 2.—SUMMARY OF THE RESULTS OF THE EFFECT OF *Cephalothecium roseum* ON THE PATHOGENICITY OF *Helminthosporium sativum* ON WHEAT SEEDLINGS (AVERAGE OF FOUR TRIALS)

Disease rating

Organisms added to sterile soil	Amount of oat-hull inoculum per pot of sterile soil	Variety: Mindum	Variety: Strain 729	Variety: Strain 726	Variety: Marquis	Variety: Strain 716	Mean of soil treatments	Standard error of means
	grms.							
Control A	0	6.8	3.1	9.0	16.5	9.3	8.9	
Control B [1]	0	13.7	9.7	15.0	15.1	13.4	13.4	
C. roseum	100	5.9	9.8	4.0	20.0	12.0	10.3	2.39
H. sativum	100	81.3	84.5	86.1	82.2	91.3	85.1	
C. roseum + *H. sativum*	50 + 50	68.6	68.8	80.1	76.9	79.9	74.9	
C. roseum + *H. sativum*	100 + 100	61.7	67.7	75.6	74.6	81.1	72.1	
Mean of varieties		39.7	40.6	45.0	47.5	47.8	44.1	
Standard error of means		2.18						

Total dry weight of plants (grams)

Organisms added to sterile soil	Amount of oat-hull inoculum per pot of sterile soil	Mindum	Strain 729	Strain 726	Marquis	Strain 716	Mean of soil treatments	Standard error of means
Control A	0	6.3	5.3	4.6	3.3	4.0	4.7	
Control B [1]	0	4.9	2.8	2.3	2.4	2.7	3.0	
C. roseum	100	5.4	3.7	3.8	2.6	3.9	3.9	0.29
H. sativum	100	1.6	0.9	0.9	0.4	0.7	0.9	
C. roseum + *H. sativum*	50 + 50	3.4	1.8	0.9	0.6	1.4	1.6	
C. roseum + *H. sativum*	100 + 100	4.2	2.3	1.4	0.9	1.8	2.1	
Mean of varieties		4.3	2.8	2.3	1.7	2.4	2.7	
Standard error of means		0.27						

[1] One hundred grams of sterile oat-hull medium added per pot of sterile soil.

Examination of the disease-rating section of Table 2 shows that the strain of *H. sativum* used in this investigation was distinctly pathogenic on wheat, while the fungus *C. roseum* was decidedly non-pathogenic. The important point in the experiment is that the presence of *C. roseum* suppressed to a significant degree the virulence of *H. sativum*. The comparative effect of these fungi alone, and in association, on wheat seedlings, is shown in Figure 2.

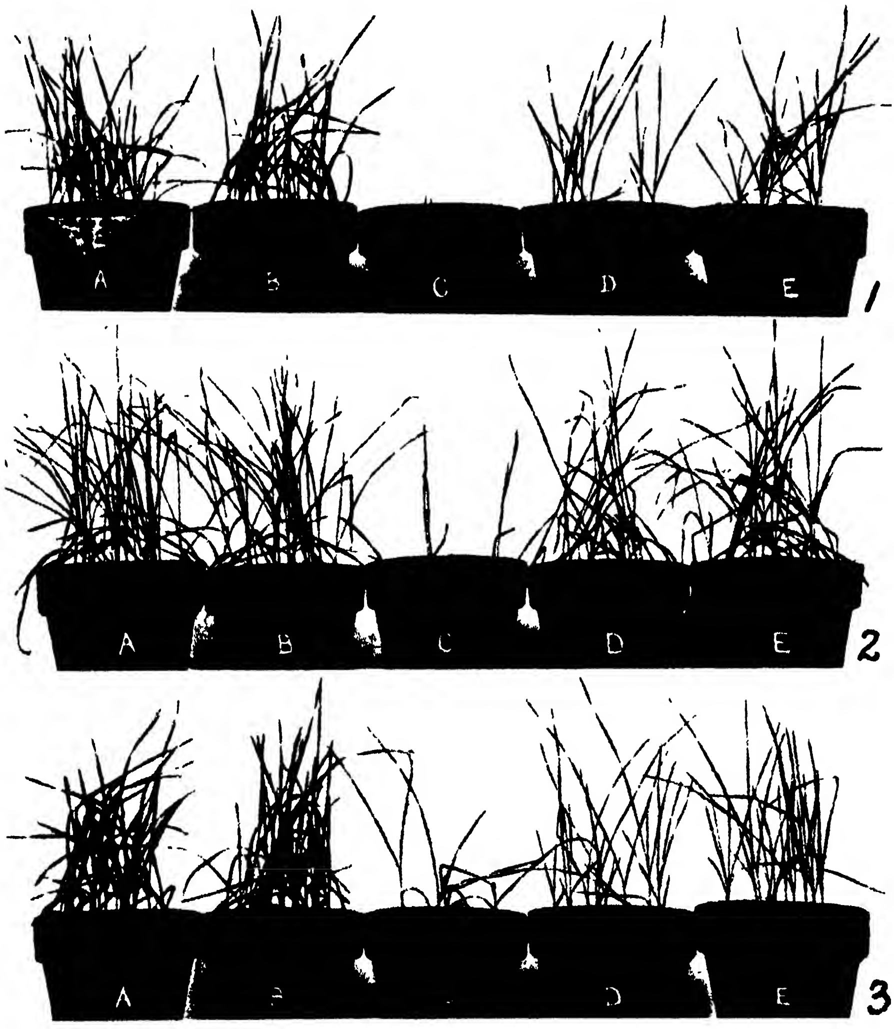

FIGURE 2—The pathogenicity of *Helminthosporium sativum* as influenced by *Cephalothecium roseum* in pot tests. Growth of wheat plants at 36 days. (1) Marquis, (2) Mindum, and (3) H–44–24 × Reward Strain 716. Arrangement of soil series: (A) Control, no fungus, sterile soil plus 100 grams of sterile oat-hull medium. (B) *C. roseum* in sterile soil, 100 grams of oat-hull inoculum. (C) *H. sativum* in sterile soil, 100 grams of oat-hull inoculum. (D) *H. sativum* and *C. roseum* in sterile soil, 50 grams of oat-hull inoculumof each fungus. (E) *H. sativum* and *C. roseum* in sterile soil, 100 grams of oat-hull inoculum of each fungus.

From the results in Table 2 it is evident that the antagonism of *C. roseum* to *H. sativum* was not significantly influenced when the amount of inoculum of each fungus added to the soil was increased from 50 to 100 grms. per pot. The results of the experiment indicate the importance of the reaction of one living micro-organism upon another in the soil, and confirm the experiments of Henry (*11*), Sanford and Broadfoot (*19*) and Garrett (*9*), who found that infection of wheat seedlings by root-rot fungi was suppressed by the antagonistic effect of certain fungi and bacteria.

It may be mentioned in passing that the analysis of the results shows that, of the varieties used in this study, Mindum was the most resistant while Marquis and H-44-24 × Reward Strain 716 were the most susceptible to attack by the strain of *H. sativum* used in the experiment.

It is difficult, even under the most carefully controlled conditions, to prevent inocula of saprophytic fungi from entering pots of sterile soil. Henry (*11*) found that the addition of a trace of unsterilized soil to pots of sterile soil served as a source of saprophytic soil organisms which subsequently produced a marked inhibitive action on the development of cereal root-rot fungi.

The results in Table 2 show significant differences between dry weight of plants grown in sterile soil and in sterile soil plus the oat-hull medium, and suggest that the addition of organic material to sterile soil stimulates the development of saprophytic organisms, thereby producing a condition of the soil environment which is unfavourable for the growth of wheat seedlings. The results seem to indicate that the competition for food among soil organisms and the staling products produced by these organisms are important factors influencing plant growth. The various inter-relationships between the soil organisms themselves and between these organisms and the plants, as well as the influence of the environment on these inter-relationships are imperfectly understood. This phase of the root-rot problem is exceedingly complex and requires further investigation.

While the results of the foregoing experiment indicate the importance of the factor of biological antagonism in the control of root-rot diseases of cereals, further studies are needed to determine the real nature of the antagonism involved.

The ability of *C. roseum* to parasitize other fungi has been reported by Whetzel (*22*) and Boning (*3*). During the course of an intensive investigation of the black knot disease of plums and cherries (*Dibotryon morbosum* (Sch.) T. and S.) Koch (*14*) found that in nature *C. roseum* actively parasitizes the stroma of *D. morbosum*, and exerts an important measure of biological control over this fungus. Sanford and Broadfoot (*19*) studied the effects of certain soil-inhabiting micro-organisms on the virulence of *Ophiobolus graminis* Sacc. and found that staling products produced by some fungi were effective in suppressing the pathogenicity of *O. graminis* in soil culture. Vasudeva (*20*), Machacek (*15*), and Sanford (*18*) concluded that the pathogenicity of certain fungi was suppressed by the staling products produced by other fungi and bacteria.

Preliminary tests were made to determine what effect staling products produced by *C. roseum* and certain other fungi on various liquid media (staled solutions) had on the germination and germ-tube growth of spores of *H. sativum*. These tests comprise a part of the physiological studies under investigation at this laboratory, the complete results of which will appear in a subsequent paper.

The results presented in Table 3 show that the germination of spores and growth of germ tubes of *H. sativum* were markedly suppressed when they were cultured in staled solutions of other fungi, particularly *Penicillium expansum* Link, *Aspergillus niger* Van Tiegh. and *Cephalothecium roseum*. The results with *C. roseum* support the view that toxic substances produced by this fungus when grown in soil were the chief factor in suppressing the virulence of *H. sativum*.

TABLE 3.—EFFECT OF STALED SOLUTIONS OF VARIOUS FUNGI ON THE GERMINATION AND GERM-TUBE GROWTH OF SPORES OF *Helminthosporium sativum* (AVERAGE FOUR TRIALS)

Germination rating of spores of *Helminthosporium sativum*[1]

Organism	Soil extract	Modified Duggar's medium	Waksman's Sucrose Peptone solution	Mean of organism
Penicillium expansum	0.0	3 5	14.6	6 0
Aspergillus niger	0 0	0 0	48.5	16.2
Cephalothecium roseum	9 8	23 7	26.7	20.1
Helminthosporium sativum	9 6	2.9	52.9	21.8
Trichoderma koningi	75.2	24 5	21.9	40.5
Fusarium culmorum	46.1	29.8	62.5	48.8
Rhizoctonia Solani	51.3	77 0	74 0	67.4
Control (no organism)	99.5	77.7	100 0	92.4

[1] Germination rating based on the percentage of spores germinated and length of germ tubes.

$$\text{Germination rating} = \frac{\text{Sum of numerical ratings of individual spores} \times 100}{\text{Total number of spores examined} \times 5 \text{ (Highest numerical rating)}}$$

The results reported in this paper were obtained under a definite set of environmental conditions and are undoubtedly much more pronounced than might be expected under field conditions. It is well known, however, that the soil supports a varied and large microflora, and that soil temperature and moisture markedly influence the biological balance in the soil. There is little doubt but that, to some extent at least, the presence of *C. roseum* in the soil exerts an inhibiting effect on the pathogenicity of *H. sativum*. The results of this study confirm the work of Henry (*11*), Sanford and Broadfoot (*19*), and Garrett (*8*, *9*), and suggest that biological antagonism may be one of the most important factors influencing the extent of damage caused by cereal root-rot fungi in the field.

SUMMARY

Greenhouse experiments have been made to determine the influence of the saprophytic fungus *Cephalothecium roseum* Corda on the pathogenicity of *Helminthosporium sativum* P., K., and B. in the soil. A detailed discussion of the methods and analysis employed in pot-culture experiments with cereal root-rot fungi are given.

A fast-growing strain of *H. sativum* was distinctly pathogenic on wheat. The pathogenicity of this strain was suppressed by the antagonistic action of *C. roseum*.

Preliminary physiological studies have shown that staling products produced by *C. roseum* on liquid media were exceedingly effective in inhibiting the germination and germ-tube growth of spores of *H. sativum*. The results suggest that the toxicity of substances produced by *C. roseum* was the chief factor in suppressing the pathogenicity of *H. sativum*.

Pot-culture experiments have demonstrated that *C. roseum* exerts a measure of natural biological control over *H. sativum*.

LITERATURE CITED

1. BAMBERG, R. H. Bacteria antibiotic to *Ustilago zeae*. Phytopath. *21* : 881-890. 1931.
2. BISBY, G. R., N. JAMES and M. TIMONIN. Fungi isolated from Manitoba soil by the plate method. Can. Journ. Res. *8* : 253-275. 1933.
3. BÖNING, KARL. Zur Biologie und Bekämpfung der Sklerotienkrankheit des Tabaks (*Sclerotinia sclerotiorum* (Lib.) Massee). Phytopath. Zeitschr. *6* : 113-175. 1933.
4. ENDÔ, S. Studies on the antagonism of micro-organisms. Bull. Miyazaki Coll. Agr. and Forestry, *3* : 95-119. 1931; *4* : 133-183. 1932; *5* : 51-73. 1933.
5. FAWCETT, H. S. The importance of investigations on the effects of known mixtures of micro-organisms. Phytopath. *21* : 545-550. 1931.
6. FISHER, R. A. Statistical methods for research workers. Fourth Edition. Oliver and Boyd, Edinburgh and London. 1932.
7. ——————, and J. WISHART. The arrangement of field experiments and the statistical reduction of the results. Imp. Bur. of Soil Sci. Tech. Comm. No. 10. 1930.
8. GARRETT, S. D. Factors affecting the pathogenicity of cereal foot-rot fungi. Biol. Revs. *9* : 351-361. 1934.
9. ——————. Factors affecting the severity of Take-all. Journ. Agr. South Australia *37* : 664-674, 799-805, 976-983. 1934.
10. GOULDEN, C. H. Modern methods of field experimentation. Sci. Agr. *11* : 681-701. 1931.
11. HENRY, A W. The natural microflora of the soil in relation to the foot-rot problem of wheat. Can. Journ. Res. *4* : 69-77. 1931.
12. JOHNSON, D. E. The antibiosis of certain bacteria to smuts and some other fungi. Phytopath. *21* : 843-863. 1931.
13. JONES, L. R., H. H. MCKINNEY and H. FELLOWS. The influence of soil temperature on potato scab. Wis. Agr. Exp. Sta Res. Bul. 53. 1922.
14. KOCH, L. W. Investigations on Black Knot of Plums and Cherries. II. The occurrence and significance of certain fungi found in association with *Dibotryon morbosum* (Sch.) T. & S. Sci. Agr. *15* . 80-95. 1934
15. MACHACEK, J. E. Studies on the association of certain phytopathogens. Tech. Bul. No. 7, Macdonald College, McGill Univ. 1928.
16. MCKINNEY, H. H Influence of soil temperatures and moisture on infection of wheat seedlings by *Helminthosporium sativum*. Journ. Agr. Res. *26* · 195-218. 1923.
17. MORITZ, O. Weitere Studien über die Ophiobolose des Weizens. Arb. Biol. Reichs. für Land-und Forstw. *20* : 27-48. 1932.
18. SANFORD, G. B. Some factors affecting the pathogenicity of *Actinomyces scabies*. Phytopath. *16* : 525-547. 1926.
19. ——————, and W. C. BROADFOOT. Studies of the effects of other soil-inhabiting micro-organisms on the virulence of *Ophiobolus graminis* Sacc. Sci. Agr. *11* : 512-528. 1931.
20. VASUDEVA, R. S. Studies in the Physiology of Parasitism. XII. On the effect of one organism in reducing the parasitic activity of another. Ann. Bot. *44* : 557-564. 1930.
21. WEINDLING, R. *Trichoderma lignorum* as a parasite of other soil fungi. Phytopath. *22* : 837-845. 1932.
22. WHETZEL, H. H A fungus living as a parasite upon another fungus. Ont. Nat. Sci. Bul. *5* : 3-4. 1909.

Résumé

Etudes sur le traitement de la pourriture de la racine des céréales causée par *Fusarium culmorum* (W.G. SM.) Sacc. et *Helminthosporium sativum* P.K. et B. II. Pathogénicité de *Helminthosporium sativum* influencé par *Cephalothecium roseum* Corda dans les essais de pots en serre. F. J. Greaney et J. E. Machacek, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

Il a été fait des essais en serre pour déterminer l'influence du champignon saprophytique *Cephalothecium roseum* Corda sur la pathogénicité de *Helminthosporium sativum* P.K et B. dans le sol. Une étude détaillée des méthodes et des analyses employées dans les essais de culture en pots des champignons de la pourriture de la racine des céréales est donnée. Une espèce à pousse rapide de *H. sativum* s'est montrée tout à fait pathogène sur le blé. La pathogénicité de cette espèce a été supprimée par l'action antagonistique de *C. roseum*. Il a été démontré par des études physiologiques préliminaires que les produits de *C. roseum* sur le milieu liquide étaient extrêmement utiles pour enrayer la germination et la végétation des tubes de germes des spores de *H. sativum*. Les résultats indiquent que la toxicité des substances produites par *C. roseum* est le facteur principal dans la suppression de la pathogénicité de *H. sativum*. Il a été démontré par des essais de culture en pots que le *C. roseum* exerce un certain contrôle biologique naturel sur le *H. sativum*.

OCCURRENCE OF "SPOTTED WILT" OF TOMATO IN ONTARIO[1]

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In 1931 the Dominion Botanist brought to the writer's attention while at Ottawa, a diseased condition of tomatoes which, though of the streak type, did not in all respects agree therewith. Specimens were sent to St. Catharines the following year but pressure of other work made it impossible to pay much attention to this disease until 1934, when fresh specimens were obtained and the disease studied.

Symptoms of the Disease at St. Catharines

At St. Catharines, under greenhouse conditions, the disease has shown symptoms that strongly suggest the trouble to be spotted wilt, as described by Samuel, Bald and Pittman (*8*) and K. Smith (*10*). The outstanding symptoms are bronzing (Plate I, 1) of young leaves on rapidly growing plants, followed by a pronounced stunting of the plant (Plate I, 2). The bronzing may take the form of spots, or may be fairly generally distributed over the leaf surface and may vary in intensity from a very inconspicuous glaze to a distinct dark brown to almost black glazed area. Generally bronzed leaves turn downward and inward, and bronzed areas often become necrotic and dry out. An additional symptom that is of some value from a diagnostic standpoint is that the leaves at the top of affected plants curl lengthwise and inwards to a very pronounced degree, giving a leaf roll appearance to the top leaves (Plate I, 3). At least this symptom has been quite constant under glasshouse conditions at St. Catharines.

The rapidity with which symptoms appear and change is remarkable. A plant at night that shows faint bronzing may the next morning exhibit definite and pronounced bronzing and prominent zoned rings may form within a few days' time. In addition to the bronzing, certain leaves and particularly certain plants have shown a profusion of brown concentric rings, or a pattern network of concentric lines, on the leaf tissue (Plate III, 4, 5 and 6). On the stalk of one old plant, and on the petioles of several young plants superficial necrotic streaks have been observed, but such necrotic streaks seem to be rare with this disease.

There are in the greenhouse at time of writing three plants which three weeks ago exhibited pronounced bronzing and cessation of growth, with no necrosis. These plants have in the meantime resumed growth and the symptoms on the secondary growth are not as pronounced as they were shortly after the plants had become infected. Though bronzing is still present, it is quite inconspicuous and might easily be overlooked. Also necrosis of tissue which was absent in the early stages of the disease is now present though not severe. In fact a somewhat superficial inspection

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[2]Plant Pathologist in charge.

of these plants might well result in a diagnosis of "streak" but a more careful examination would show that bronzing was present, and that much of what at first might be taken for necrosis is actually "black bronzing" which from above looks something like "necrosis"

All these symptoms as observed at St. Catharines are in such close agreement with those described for spotted wilt by Samuel, Bald and Pittman (*8*) that there would appear to be little room for doubt but that this disease, or one closely related to it, is now present in Ontario. So far, however, this disease has been studied under glasshouse conditions only, and therefore additions to the symptomatology may have to be made after it has also been studied under field conditions.

Symptoms of Spotted Wilt Distinct from Tomato Streak

It might be well at this time to point out that the symptoms of spotted wilt are quite distinct from streak. Generally the first symptom of streak is a black necrosis of the leaf or stem tissue, with or without accompanying mosaic mottling. This necrosis generally progresses rapidly until the outstanding symptom of streak is black necrosis, particularly of stem, petiole and leaf, though the fruit also is often affected with raised, black, irregularly-shaped areas. In the case of spotted wilt, however, the initial symptom on tomato is a bronzing of the leaf surface with or without "rings" and various patterns made up of "concentric lines." No necrosis of leaf or stem tissue is present at first, but later some necrosis may occur (Plate I, 1), though it is generally absent, and, if present, is but slight in extent compared with streak. On the fruit also the difference in symptoms is pronounced as spotted wilt generally occurs as bronze or yellow blotches often in the form of almost perfect concentric circles.

Literature

Spotted wilt was first found near Melbourne, Australia, by Brittlebank (*3*) in 1919. A more complete description of the disease, including the insect vectors, was published in 1930 by Samuel, Bald and Pittman (*8*) and in 1931 by Bald and Samuel (*1*). In 1931 K. Smith (*11*) reported this same disease as occurring in the British Isles. In his second paper Smith (*10*) describes the symptoms, insect vectors and host range in considerable detail. In 1929 Beecher and Shapovalov (*2*) and later Shapovalov (*9*) report a tomato die-back which they say is "symptomatologically similar to spotted wilt." In 1930 Doolittle and Sumner (*5*) described a diseased condition of tomatoes as found in Wisconsin which they considered to be spotted wilt. Later in 1934 (*6*) they published the evidence on which their previous report was made. In 1932 Conners (*4*) reported spotted wilt in the Canadian Plant Disease Survey for that year, as having been found in Saskatchewan. In 1934 McWhorter (*7*) reported that the English form of spotted wilt occurred in Oregon.

Distribution

The distribution of spotted wilt is as follows: Australia—Victoria, New South Wales, South Australia, West Australia, Queensland and Tasmania; British Isles; United States of America—Oregon, Wisconsin and California; and Canada—Ontario and Saskatchewan.

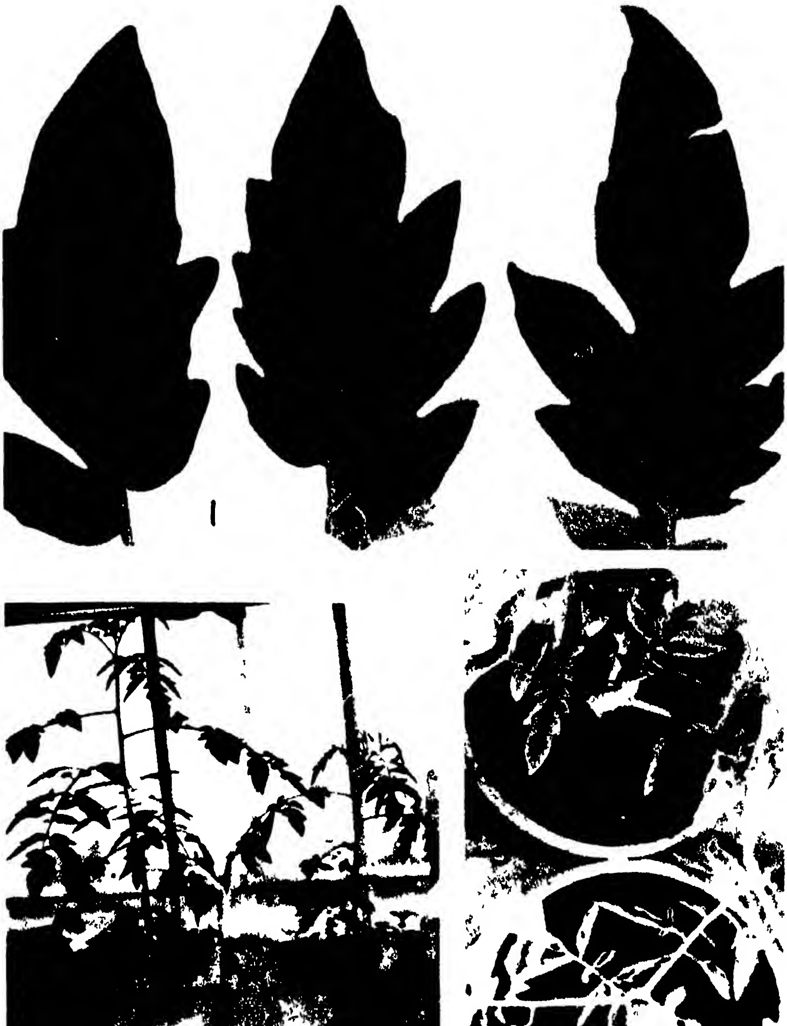

PLATE I. 1. Leaves of Grand Rapids variety showing characteristic bronzing. This bronzing appears as a brown, glazed area. Necrosis is apparent towards tip of right-hand leaf. 2. Healthy tomato plant (left) and spotted wilt plant (right). Note stunting of diseased plant and curling inwards and downwards of top leaves. 3. The tips of two tomato plants, healthy (above) and spotted wilt (below). Note 'leaf rolling' of diseased plant.

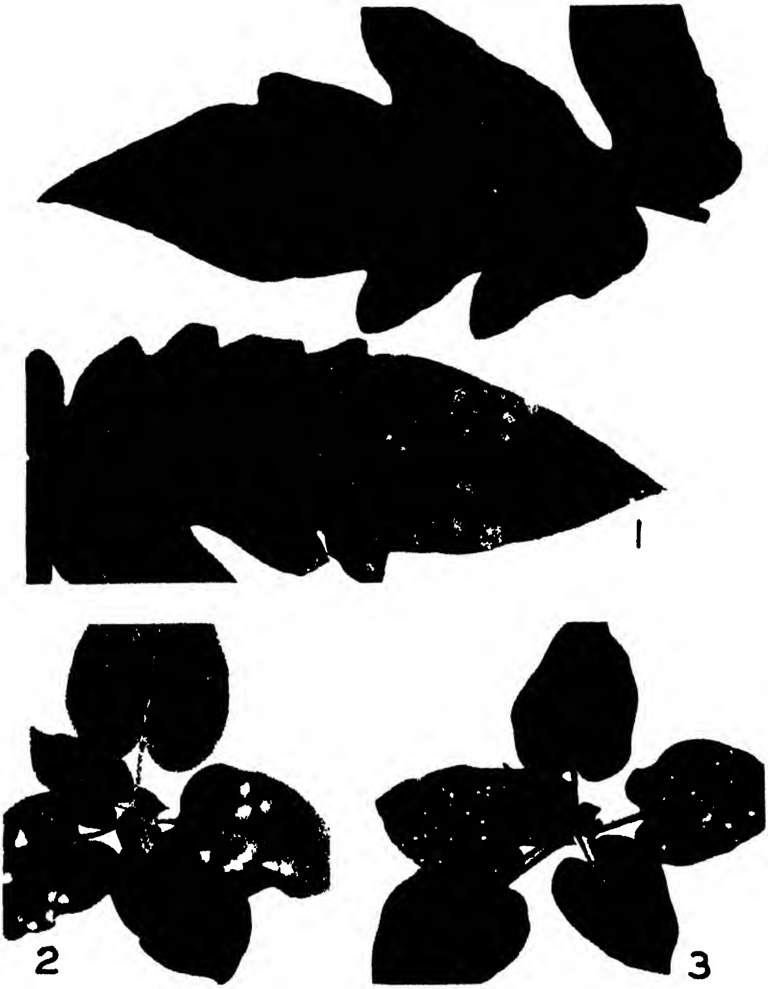

PLATE II 1 Spotted wilt on tomato leaves of Grand Rapids variety Note 'rings' and 'spots' characteristic of this disease 2 Spotted wilt on *Nicotiana glutinosa* (left), and tomato streak (single virus) on *Nicotiana glutinosa* (right). Note that the local necrotic lesions produced by spotted wilt virus are much larger than those produced by tomato streak virus.

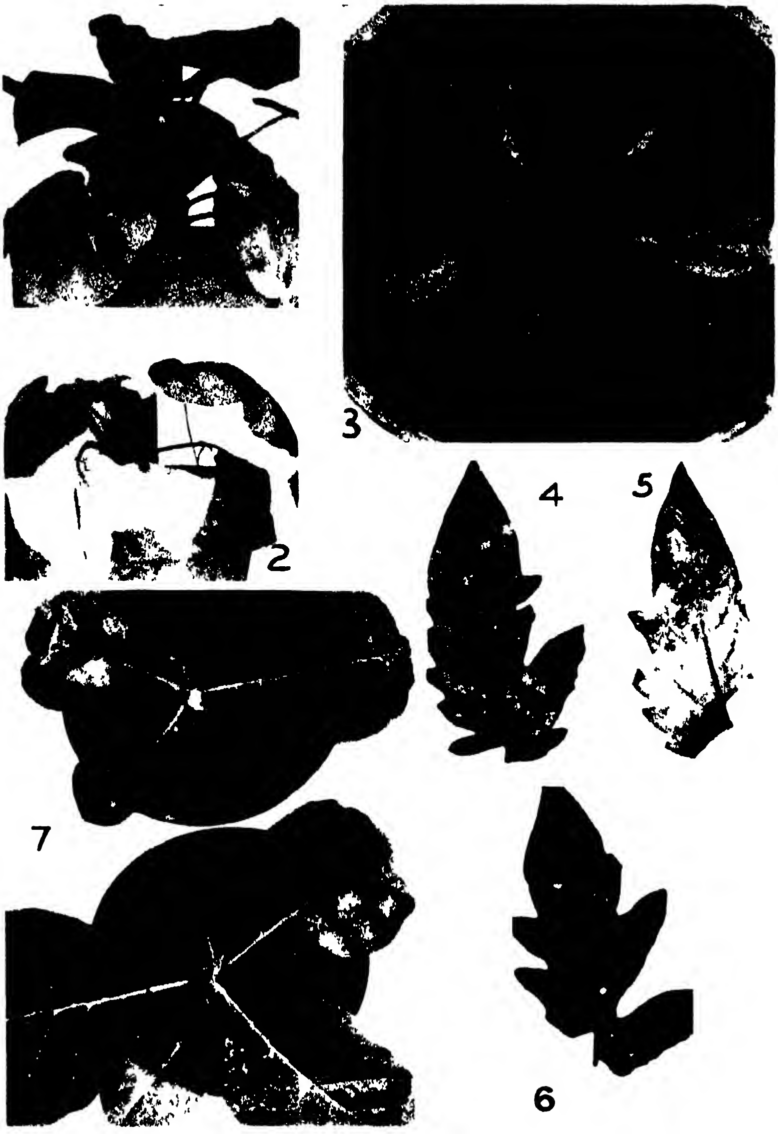

PLATE III. 1. Spotted wilt virus in *Nicotiana glutinosa*. Note local necrosis at arrow and systemic necrosis in tip of plant. 2. Later stage of spotted wilt on *N. glutinosa*. Plant wilted and almost dead. 3. Spotted wilt on Petunia. Note local necrotic lesions which showed up three days after inoculation and were photographed ten days after inoculation. 4, 5, and 6. Spotted wilt on tomato, showing concentric rings and 'patterns' of concentric lines. 7. Spotted wilt on tobacco (Burley, Standup Resistant) showing large local necrotic lesions and systemic necrosis.

Importance of Spotted Wilt

In Australia and England where this disease has been under investigation for some years spotted wilt is considered to be a very serious disease. In this connection Brittlebank (Australia) (*3*) writes "Spotted wilt was first observed during the 1915-16 season, when the injury was slight owing to the restricted area over which the disease had spread, and to the comparatively small number of plants affected. In the following year the number of diseased plants had increased to an alarming extent. The present season (1918–19) has, to say the least, been disastrous, and fully 50 per cent of suburban garden plants have been destroyed. In the county districts the disease has made considerable progress and diseased plants have been found in nearly all parts of Victoria." K. Smith (*10*) England, writes "In the writer's opinion spotted wilt is the cause of considerable loss to the tomato growing industry in the British Isles . . . ." Also as K. Smith points out, spotted wilt is apt to be more serious in a glasshouse where plants of various kinds are propagated, since in such a house the chances of "over wintering" are greatly increased, due to the fact that the spotted wilt virus attacks not only the tomato but many other plants as well, such as primula, gloxinia, cineraria, dahlia, winter cherry, chrysanthemum, aster, zinnia, petunia, lupine, etc. Any one of these plants may well act as a "carrier" in "over wintering" the virus from one host to another.

Just how spotted wilt will behave in Canada has yet to be ascertained. The climate in Canada is so varied and dissimilar to that in either Australia or England that the question of possible importance in Canada cannot be answered at this time.

At the present time its known distribution in Canada is confined to Ontario and Saskatchewan. However, as there is every possibility that this disease may be serious in Canada if it becomes widely distributed, every effort should be made to ascertain its present distribution. It is with this idea in mind that this preliminary paper is published so as to establish the fact of its presence in Ontario in order that plant pathologists and growers alike may be on the look-out for it.

Experimental

Inoculations were effected by mechanical sap transfer by means of gentle rubbing with a pad of absorbent cotton moistened with the virus. It was found that the percentage of successful inoculations was comparatively low since in several tests only two out of six plants became infected. In a few tests where young vigorously-growing tomato plants were inoculated with virus obtained from a recently-infected plant, 100% positive results were obtained.

In all, twenty *Nicotiana glutinosa*, twenty *Nicotiana tabacum* (tobacco, Standup Resistant), twenty-five Petunia (garden variety) and fifty *Solanum lycopersicum* (tomato, Grand Rapids) have been inoculated, and characteristic symptoms obtained on all hosts.

In the first series of inoculations four plants each of tomato, tobacco and *N. glutinosa* were inoculated and systemic necrosis occurred on one

tobacco plant only. All the other inoculations gave negative results. Sub-transfers were made from this necrotic tobacco plant to two plants each of tomato, tobacco and *N. glutinosa*, with negative results in every case. Later another series was inoculated with inoculum from the same plant, and positive results were obtained on all tomato and *N. glutinosa* plants, but none on tobacco.

In another series six plants were inoculated and positive results were obtained on one *N. glutinosa*, one tobacco and two tomato plants. A later series of inoculations gave 100% positive results on tobacco and *N. glutinosa* but only 50% on tomato.

As has been recorded by Smith (*10*) the petunia is a very suitable host to use as indicator as it produces local lesions within two days' time. At St. Catharines the garden variety of petunia has given local lesions in from two to three days' time, another point which suggests that the virus under investigation here is similar to the English spotted wilt virus.

As a result of successful inoculations on four different hosts, the following symptoms were obtained:—

Tomato: The symptoms have already been outlined above, but bronzing and severe stunting of growth in young plants, and the curling lengthwise and inwards of younger leaves may be mentioned here (Plate I, 1, 2 and 3; Plate III, 4, 5 and 6).

Tobacco: Generally the first symptom takes the form of large local lesions on inoculated leaves followed by severe systemic necrosis and death of plant (Plate III, 7).

Nicotiana glutinosa: Here also the first symptom takes the form of large local lesions followed by systemic necrosis (Plate II, 2; Plate III, 1 and 2). In some cases no local lesions developed, though systemic necrosis resulted in death of plant.

Petunia: Within three days from time of inoculation, circular brown local lesions (Plate III, 3) occur on the rubbed leaves. Later the centre of these spots becomes yellowish, while the margin remains black.

The viruses of "spotted wilt" and "single virus streak" both produce local lesions on *Nicotiana glutinosa* and *N. tabacum*. A comparison of the local lesions produced by these two viruses points out (*1*) that the spotted wilt virus produces a much larger lesion on both *N. glutinosa* and *N. tabacum* than does the single streak virus, and (2) that on *N. glutinosa* the local lesion produced by the single streak virus has a much more pronounced outer ring of dark brown colour than does the local lesion produced by spotted wilt virus.

On *N. tabacum* the spotted wilt virus produces lesions with a diameter of 5 to 7 mms. six days after inoculation, whereas the single streak virus produces lesions with a diameter of only 1 to 2 mms. in the same time.

On *N. glutinosa* the spotted wilt virus produces lesions with a diameter of 2 to 3 mms., whereas the single streak virus produces lesions of only 1 mm. in diameter in the same time (Plate II, 2 and 3).

Longevity of the Virus

According to Bald and Samuel (*1*), and Smith (*10*) who have studied spotted wilt in Australia and England respectively, the potency of the virus lasts for only four to five hours after it has been extracted from the plant. Both investigators agree that after six hours the virus has lost its potency.

A single test made at St. Catharines would indicate that the virus under investigation here has also a very short period of potency.

TABLE 1.—EFFECT OF STANDING ON VIRUS

Number of plants inoculated	Number of plants infected after			
	Fresh	½ hour	2 hours	6 hours
3 petunia in each case	3	2	-	-

This test would indicate that the virus being investigated at St. Catharines loses its potency somewhere between ½ hour to 2 hours after standing at room temperature.

Resistance to Heat

Australian spotted wilt is inactivated by heat at very low temperatures. Bald and Samuel (*1*) give the thermal death-point as in the neighbourhood of 42° C., for ten minutes heating. A preliminary test at St. Catharines has shown that the virus under observation here is inactivated by heating at 45° C., for ten minutes.

These preliminary results present good evidence for considering that spotted wilt is now present in Ontario.

Suggested Control Measures

Spotted wilt is a "virus" disease that is known to be spread by *Thrips tabaci* Lind., and Thrips *Frankliniella insularis*. Also since the disease can be spread artificially by juice transfer it is quite likely that spread may take place in a greenhouse during pruning and stopping operations.

Therefore if this disease is found in a greenhouse, or field, it is advisable to destroy all diseased plants so as to cut down the possibility of spread. In the greenhouse, thrips should be kept down to a minimum.

In case of doubt as to diagnosis it is suggested that *fresh* specimens of suspected plants be sent to the St. Catharines laboratory for diagnostic purposes. As the virus of this disease lives only a short time in plant parts when excised, it is suggested that specimens sent in include, when possible, green fruits. The virus apparently exists longer in green fruits than in other parts of the plant.

REFERENCES

1. BALD, J. G. and SAMUEL, G. Investigations on "spotted wilt" of tomatoes II. Coun. for Sci. & Ind. Research, Melbourne, Australia, Bull. *54*. 1931.
2. BEECHER, F. S. and SHAPOVALOV, M. Tomato die-back. Plant Dis. Rep. *13* : 148. 1929.
3. BRITTLEBANK, C. C. A new tomato disease—"spotted wilt." Jour. of Agr., Vict. *17* : 231-235. 1919.
4. CONNERS, I. L. Canadian Plant Disease Survey, *12* (1932): 57. 1933. (mimeographed).
5. DOOLITTLE, S. P. and SUMNER, C B. Occurrence of Australian spotted wilt of tomatoes in Wisconsin. Phytopath. *21* : 106. 1931.
6. ——————————. Probable occurrence of Australian spotted wilt in Wisconsin. Phytopath. *24* : 943-946. 1934.
7. McWHORTER, F. P. English form of tomato spotted wilt found in Oregon greenhouse. Plant Dis. Rep. *18* : 25-26. 1934.
8. SAMUEL, G., BALD, J. G. and PITTMAN, H. A. Investigations on "spotted wilt" of tomatoes. Coun. Sci. & Ind. Res., Australia. Bull. *44*. 1930.
9. SHAPOVALOV, M. Die-back form of tomato streak. Phytopathology *23* : 928. 1933.
10. SMITH, KENNETH M. Studies on plant virus diseases XI. Ann. App. Biol. *19* : 305-330. 1932.
11. ——————. Studies on potato virus diseases, VIII, On a ring-spot virus affecting solanaceous plants. Ann. of Appl. Biol., *18* : 1-15. 1931.

Résumé

La brûlure en taches des tomates fait son apparition dans l'Ontario. G. H. Berkeley, Laboratoire fédéral de pathologie végétale, St. Catharines, Ont.

Il a été démontré par des essais d'inoculation que la maladie à virus des tomates connue sous le nom de "Brûlure en taches" (*Spotted Wilt*) sévit actuellement dans l'Ontario, au Canada. L'auteur décrit les symptômes de la maladie sur la tomate, le tabac, le pétunia et le *Nicotiana glutinosa* et il indique la longévité du virus (2 heures) et sa résistance à la chaleur (45° C.). La liste des hôtes connus du virus comprend 13 plantes. Les moyens répressifs recommandés consistent à arracher les plantes malades et à réduire au minimum le nombre de *Thrips*.

THE PHYSIOLOGY OF *RHIZOCTONIA SOLANI* KÜHN[1]

III. THE SUSCEPTIBILITY OF DIFFERENT PLANTS AS DETERMINED BY SEEDLING INFECTION

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The object of determining the susceptibility of different seedlings to infection by *Rhizocotonia Solani* Kuhn, was to find resistant crops suitable for planting in rotation upon Rhizoctonia infested soils, to aid in the control of this fungus. This fungus is known to attack over 160 species of plants (*3*) including field, vegetable and ornamental crops and weeds (*5*). Not only is it a destructive parasite on many crops but is also a saprophyte capable of existing indefinitely on dead organic matter in the soil (*5*). However, it has been found that the amount of the fungus in the soil is usually great before serious infection takes place (*5*, *8*). It is probable that the planting of susceptible crops will aid in the maintenance and increase of this fungus in the soil. On the other hand the planting of resistant crops may tend to reduce the infestation in soils. This possibility is suggested by the work of Chamberlain (*1*) who found a reduction in soil infection when potatoes followed grass but not when following cereals, peas or turnips.

Although, as mentioned above, over 160 species of plants have been found to be susceptible to *Rhizocotonia*, much evidence of varietal resistance has been observed and recorded. Zeller (*11*) working on black root of strawberries found that Clark's Seedling, Marshall and Magoon are susceptible, while Ettersburg 121 and the wild coast strawberry (*Fragaria chiloensis* Duchesne) are either immune or highly resistant. Tilford (*10*) observed that Kentucky Blue Grass (*Poa pratensis* L.), Crab grass (*Panicium sanguinale* L.), Bermuda grass (*Cynodon dactylon* L.), and white clover (*Trifolium repens* L.), are immune while red fescue (*Festuca rubra* L.) and some of the bent grasses (*Agrostis* spp.) are susceptible. Teng (*9*) working on *Rhizoctonia* of lobelia found that *L. erinus* L. var. *gracilis*, was resistant to infection but *L. erinus* L. var. *speciosa* and *L. ramosa* L. succumbed to infection when the roots were wounded and under the same conditions. *L. cardinalis* L. was markedly stunted.

EXPERIMENTAL

Two types of experiments were carried out. In the first the seedlings were grown on a nutrient agar,[3] in Petri dishes previously inoculated with a strain of the fungus isolated by germinating the sclerotia from a Netted Gem potato grown at the Experimental Station, Saanichton, B.C. The seed was first surface sterilized by immersion in a 1 : 1000 solution of mercuric chloride. This treatment was followed by a rinse and a one-hour soak in sterile tap water. Smooth seeds such as peas and beans were

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[3] The formula found to be most satisfactory for seedling and fungus development was made up as follows:

Potassium nitrate	10 g	Sucrose	20 g
Potassium di hydrogen phosphate	5 g.	Agar	15 g
		Water	1000. cc.
Magnesium sulphate	2 5 g.		
Iron chloride	trace		

TABLE 1.—SHOWING THE PATHOGENICITY OF *Rhizoctonia Solani* KUHN TO DIFFERENT PLANT

A. As determined by the lesions on the roots when the seedlings were grown on nutrient agar inoculated with the fungus.
B. As determined by the lesions on the roots when the seedlings were grown on inoculated soil.
C. As determined by the growth of the plants.

Species	Variety	A	B	C
Vetch	Purple	10	—	—*
	Oregon	8	2	2
	Hungarian	8	—	—
Pea	Champlain	8	—	—
	Capital	8	3	3
	Blue Bell	5	2	2
Bean	Yellow Eye	10	3	2
	Ede's Pole	9	3	2
Alfalfa	Grimm	10	0	1
	Cossack	10	—	—
Clover	Chateaugay—Red	10	0	0
	Early Swedish—Red	6	0	2
	Late Swedish—Red	10	—	—
	Crimson	10	0	0
	Mammoth White Dutch	10	0	0
Turnip	Canadian Gem	10	0	7
	Derby Bronze Green Top	10	0	7
Millet	Common	1	3	2
	Siberian	5	3	3
	Hungarian	0	—	—
	Japanese	0	—	—
Wheat	Marquis	1	0	0
	Red Fife	1	—	—
	Sun	1	0	—
Barley	Bark's	2	0	4
	Star	2	—	—
	Gold	2	—	—
Oats	Victory	2	0	0
	Banner	3	—	—
Corn	Longfellow	7	4	2
	Northwest Dent	4	4	2
Buckwheat	Japanese	6	2	2
Sunflower	Russian Giant	10	1	2
Rye Grass	English Perennial	2	1	1
Timothy		5	4	4
Carrot	Oxheart	9	0	7

*The minus sign indicates that no records were secured.

satisfactorily sterilized by a two- or three-minute immersion period in the disinfectant but periods of an hour or more were required in the case of seeds with hulls. In the case of oats and barley the germination was often

destroyed before aseptic growth was obtained. In order to allow time for the seeds to germinate before coming in contact with the fungus they were placed about half an inch from the advancing boundary of the mycelia. Check cultures consisted of duplicate lots of seed planted on sterile agar plates. The cultures were allowed to develop at 25° C., but owing to investigations indicating that *Rhizoctonia Solani* is most virulent at from 16° to 23° C. (*2*, *5*) a series was kept at room temperature which varied from 12° to 22° C. However, the degree of infection obtained in this series of cultures was comparable with that obtained in the cultures kept at 25° C.

In the second type of experiment the seedlings were grown in cold frames in pots inoculated by stirring into the soil cooked barley on which the *Rhizoctonia* had been grown. Before this inoculation, the soil was autoclaved for three hours at 20 lbs. steam pressure. Checks of uninoculated autoclaved soil were maintained.

In each experiment a minimum of 50 plants of each variety were carefully examined for lesions. Each seedling was given a pathogenicity value of from 0 to 10, determined by the lesions on the roots. The 0 figure represents complete freedom from lesions and the figure 10 complete destruction or coverage by lesions, 5 an intermediate condition, and so on. In the case of the seedlings in the pots an additional pathogenicity value of from 0 to 10 was given determined by the growth of the plant. The figure 0 represents normal growth and the figure 10 absence of growth. The results are given in Table 1.

FIGURE 1—The effect of *Rhizoctonia solani* Kuhn on the growth of clover and alfalfa. Top row—Red Clover (Chateaugay), Red Clover (Early Swedish). Bottom row—Alfalfa (Grimm), Mammoth White Dutch Clover.

In each case the pot on the left is a check, that on the right is inoculated with *Rhizoctonia.* Note the slight stunting of Early Swedish Red Clover and alfalfa.

It will be noted from the table that the figures obtained in the two experiments are not in accord: *e.g.*, clover seedlings were severely injured by the fungus when grown on agar but no noticeable inhibition of growth occurred when the same seed was planted in infested soil as can be seen in Figure 1. No explanation can be offered beyond suggesting that the resistance of clover to *Rhizoctonia* increases with age. Unpublished data[4] show that the water extracts of mature red clover roots inhibit the growth of *R. Solani* in pure culture.

When grown on the nutrient agar, wheat, barley, oats, rye grass and millet, with the exception of the Siberian variety, were quite resistant, while all the legumes, Swede turnips and sunflower were quite susceptible to attack by the fungus. Buckwheat, corn and timothy were somewhat intermediate.

Wheat, oats and rye grass, were likewise resistant to *Rhizoctonia* attach when grown on infested soil. Sunflower on the contrary was very susceptible when grown on the agar but was highly resistant when grown on infested soil. Timothy and corn seedlings were injured but not severely when grown on both infested agar and soil cultures.

The most noticeable feature of the pot experiment was the marked stunting of turnips and carrots although they were not visibly attacked by the fungus (Figure 2). The growth of the timothy in the inoculated

FIGURE 2—The effect of *Rhizoctonia solani* Kühn on the growth of swede turnips (Canadian Gem) Top row. Bottom row—Timothy and carrot (Oxheart).

[4] Ann. Report, 1932, Laboratory of Plant Pathology, Saanichton, B.C

pots was also greatly reduced but in this case there were conspicuous lesions visible upon the roots. Barley was also stunted in the inoculated pots. In this case it was observed that sclerotia were so abundant that the roots were quite rigid for the first half inch or more from the seed although no definite lesions could be found. This condition also applied in the case of wheat and oats though the plants were not stunted. A few sclerotia were observed on the roots of all plants but were not sufficiently numerous to deserve comment.

With the possible exception of the Blue Bell pea, no definite evidence of varietal difference in susceptibility was observed. This variety was significantly less susceptible than Champlain or Capital when grown on the nutrient agar, and appeared to be slightly more resistant when grown in infested soil. Early Swedish Red clover was more resistant than Chateaugay or Mammoth White Dutch in the agar cultures. Although all the clovers were highly resistant as determined by the growth of seedlings on infested soil the Early Swedish variety was slightly stunted or apparently less resistant than the others.

It was thought that the marked stunting of carrots and turnips might be due to the more or less exclusive presence of the *Rhizoctonia* fungus in the soil for the inoculum was stirred into the soils shortly after they were taken from the autoclave. Accordingly, 36 eight-inch pots were filled with soil, 18 of which were sterilized in the autoclave for three hours at 20 lbs. pressure. Nine autoclaved pots and nine unheated pots were then uniformly inoculated by stirring in *Rhizoctonia* infested cooked barley seed; the others were kept as checks. The series therefore consisted of autoclaved soil inoculated with *Rhizoctonia*, unheated soil, and unheated soil inoculated with *Rhizoctonia*. The pots were sown with turnips (Canadian Gem) Carrots (Oxheart) and wheat (Marquis). Wheat was included for comparative purposes for in the previous experiment wheat was not significantly affected by the presence of *Rhizoctonia* in the soil.

The growth of these plants at the end of six weeks is shown in Table 2.

TABLE 2.—SHOWING THE HEIGHT AT THE END OF SIX WEEKS OF WHEAT, TURNIPS, AND CARROTS, GROWING IN AUTOCLAVED SOIL, AUTOCLAVED SOIL INOCULATED WITH *Rhizoctonia*, UNHEATED SOIL AND UNHEATED SOIL INOCULATED WITH *Rhizoctonia*.

	Height in cms.		
	Wheat	Turnips	Carrots
Autoclaved soil	16	10	3 5
Autoclaved soil inoculated	10	4	1 5
Unheated soil	16	9	3 0
Unheated soil inoculated	10	4	1 5

It is apparent from the data in Table 2 that the stunting of wheat, turnips and carrots was not due to the soil being more or less exclusively occupied by the *Rhizoctonia* fungus, for when unheated soil was inoculated with *Rhizoctonia* the growth of all these crops was inhibited. As in the previous experiment no lesions were found on the roots of turnips or carrots. An examination of the wheat seedlings from infested soil showed that many roots had turned brown at the tips and were dying back. This condition was similar to a stunting disease of cereals described by Samuel (7) which was caused by *Rhizoctonia*. No evidence of parasitism of wheat was

obtained in the first series reported in Table 1. In the series reported in Table 2, the evidence of parasitism of wheat in addition to turnips and carrots may be attributed to the greater humidity of the chamber of the greenhouse in which the seedlings were grown. The effect of humidity on the parasitism of *Rhizoctonia* is described by Park and Bertus (*4*) who found that this fungus is capable of infecting and killing young rice seedlings under humid conditions, but its activity is in a large measure inhibited under conditions of medium and low humidity.

SUMMARY

1. As judged by the growth of seedlings on infested soil, wheat, oats, red clover, crimson clover, and Mammoth White Dutch clover, appear to be immune or highly resistant. Alfalfa, sunflower, and rye grass are quite resistant, while peas, beans, vetch, buckwheat and timothy are moderately or highly susceptible to *Rhizoctonia Solani* Kühn.

2. Turnips and carrots are markedly stunted when grown on infested soil but exhibit no lesions or other symptoms of infection.

3. The growing of seedlings on a nutrient agar inoculated with *Rhizoctonia* is not a satisfactory method of determining their relative resistance to the fungus, *e.g.*, clovers and sunflower show maximum susceptibility when grown on agar but are highly resistant when grown on infested soil.

LITERATURE CITED

1. Chamberlain, E. E. Corticium disease of potatoes. I. Propagation and spread of the disease. New Zealand Jour. of Ag. *43* : 204-209. 1931.
2. Hemmi, T. On the relation of temperature to the damping off of garden-cress seedlings by *Pythium deBaryanum* and *Corticium vagum*. Phytopath. *13* : 273-281. 1923.
3. Muller, K. O. Untersuchungen zur Entwicklungsgeschichte und Biologie von *Hypochnus Solani* P.u.D. (*Rhizoctonia Solani* K.). Arb. Biol. Reichsanst. Land- und Forstwirtsch. *12* : 198-262. 1924.
4. Park, M. and L. S. Bertus. Sclerotial diseases of rice in Ceylon. I. *Rhizoctonia Solani* Kuhn. Ann. Roy. Bot. Gard. Peradeniya *9* : 319-31. 1932.
5. Peltier, G. L. Parasitic Rhizoctonias in America. Univ. Ill. Ag. Exp. Sta. Bul. 189. 1917.
6. Richard, B. L. Further studies on the pathogenicity of *Corticium vagum* on the potato as affected by soil temperature. Jour. Agric. Res. *13* : 761-770. 1923.
7. Samuel, G. and S. D. Garret. *Rhizoctonia Solani* on cereals in South Australia. Phytopath. *22* : 827-836. 1932.
8. Sanford, G. B. The limitations of treatment for potato tubers against scab and Rhizoctonia. Am. Pot. Jour. *8* : 11-13. 1931.
9. Teng, S. C. Rhizoctoniosis of Lobelia. Phytopath. *19* : 585-588. 1929.
10. Tilford, P. E. Brown patch of lawns and gold greens. Ohio Agr. Exp. Sta. Bul. *117* : 185-187. 1925.
11. Zeller, S. M. A strawberry disease caused by Rhizoctonia. Ore. Agr. Exp. Sta. Bul. *295*. 1932.

Résumé

La Physiologie de *Rhizoctonia Solani* Kühn, III. Sensibilité de différentes plantes déterminée par l'infection des plantules. W. Newton et N. Mayers, Laboratoire fédéral de pathologie végétale, Saanichton, C.-B.

A en juger par la pousse des plantules sur terre infectée, le blé, l'avoine, le trèfle rouge, le trèfle incarnat et le grand trèfle blanc de Hollande, paraissent être réfractaires ou hautement résistants. La luzerne, les tournesols, et le ray-grass sont très résistants, tandis que les pois, les fèves, les vesces, le sarrasin et le mil sont modérément ou hautement sensibles au *Rhizoctonia Solani* Kühn. Les navets et les carottes cultivés sur sol infecté deviennent très rabougris, mais n'exhibent aucune lésion ni d'autres symptômes d'infection. La culture de plantules sur de l'agar nutritif, inoculé avec la Rhizoctonie, n'est pas un moyen satisfaisant de déterminer leur récistance relative au champignon; les trèfles et les tournesols cultivés sur de l'agar font preuve d'une sensibilité maximum mais ils sont hautement résistants lorsqu'ils sont cultivés sur sol infecté.

THE PHYSIOLOGY OF *RHIZOCTONIA SOLANI* KÜHN[1]

IV. THE EFFECT OF A TOXIC SUBSTANCE PRODUCED BY *RHIZOCTONIA SOLANI* KÜHN WHEN GROWN IN LIQUID CULTURE, ON THE GROWTH OF WHEAT, CARROTS, AND TURNIPS

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The products excreted by fungi into the liquid media in which they are grown have been shown by many workers to exert conspicuous toxic effects upon living plant tissue. Liesau (*2*) found that *Didymella Lycopersici*, Sacc., the causal organism of tomato wilt, produced a toxin when grown in Richard's solution which caused a rapid wilting of cut tomato stems. Haymaker (*1*) observed that *Fusarium Lycopersici* Sacc. also produced a substance which caused a wilting of cut tomato stems. He also found a definite correlation between the pathogenicity of the latter organism and the toxicity of its by-products. That is, varieties of tomato which were resistant to attack by the fungus were likewise little injured by the excretory products. Other workers (*4*) have demonstrated the presence of toxins in the filtrate from liquid cultures of *Fusarium vasinfectum* Atk. and *Ophiobolus graminis* Sacc. which cause wilting and which inhibit the germination of seeds.

In a previous paper (*3*) we reported that turnips and carrots grown in pots containing soil infected with *Rhizoctonia Solani* Kühn were markedly stunted while wheat was not affected. As the stunted plants bore no visible signs of infection it was thought that the stunting might be due to some substance produced by the fungus which is toxic to turnips and carrots but not to wheat. Accordingly experiments were undertaken to determine the effect of the filtrate from liquid cultures of *Rhizoctonia* on the growth of these plants.

EXPERIMENTAL

A strain of *Rhizoctonia Solani* Kühn isolated by germinating the sclerotia on a Netted Gem potato was grown on Richard's solution[3] in large Erlenmeyer flasks for about three months, at room temperature (approx. 20° C.). At the end of this period the mycelial mats were removed and the medium filtered. The presence of a toxin in this filtrate was shown by the fact that turnip seedlings rapidly wilted when the normal or heated filtrates were added to the nutrient solution in which they were growing. When this toxin was found to be stable to heat, the filtrates from all the flasks were mixed, sterilized in the autoclave and maintained as a stock solution of toxin.

A preliminary experiment on the comparative resistance of wheat and turnip seedlings was performed by adding the filtrate to liquid cultures in which the seedlings were being grown. It was observed that the turnip seedlings wilted more rapidly and in the presence of more dilute concentrations than in the case of wheat.

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This greater resistance of wheat to the toxic factor compared with turnips was substantiated by the following experiment. Three-inch pots were filled with well washed sand, which had been previously sterilized in the autoclave for one hour at 20 lbs. pressure. The holes in the bottom of the pots were first sealed with paraffin in order to prevent any liquid from running through. They were then sown with wheat (Marquis), turnips (Canadian Gem) and carrots (Oxheart). The sand in each pot was saturated with 150 cc. of a nutrient[4] solution to promote growth.

When the seedlings were well established they were thinned out so that only ten remained in each pot. The filtrate was then added at the rate of 10 cc. each day for a period of 15 days. Checks were maintained by adding the same amount of the original sterile Richard's solution. The seedlings were allowed to grow for another seven days. They were then removed from the pots and the roots washed free from sand. The average dry weight of the roots and tops of the seedlings in each pot is shown in Table 1.

[3] *Richard's solution*

NH_4NO_3	10 gms.
KH_2PO_4	5 gms.
$MgSO_4$	2 5 gms.
$FeCl_3$	trace
Cane sugar	50 gms.
Water	1000 ccs.

[4] *Nutrient solution*

KNO_3	.1 gm.
KH_2PO_4	1 gm.
$MgSO_4$	1 gm.
$Ca(NO_3)_2$	4 gm.
$FeCl_3$	trace
Water	1000 cc.

TABLE 1.—SHOWING THE INFLUENCE OF THE STERILIZED FILTRATE FROM A THREE MONTHS OLD CULTURE OF *R. solani* ON THE GROWTH OF WHEAT, TURNIPS AND CARROTS

	Wheat Wt. in gms.			Turnips Wt. in gms.			Carrots Wt. in gms.		
	Tops	Roots	Total	Tops	Roots	Total	Tops	Roots	Total
Check	602	420	1 022	.471	.163	.634	141	.044	.185
Treated	634	477	1 111	252	055	.307	.099	022	.121

It is seen from this table that the growth of carrots is reduced by about one-third and that of turnips about one-half by the filtrate. In contrast to this the growth of wheat treated with the filtrate is slightly but not significantly greater than the growth upon the check pots.

Owing to the difficulty of evaluating the effect of residual sugar and salts when filtrates from fungus cultures are added to plant cultures, it was thought desirable to prepare an extract in which the nutrients in the filtrate were reduced to a minimum. An extract of the washed and dried mycelium from liquid cultures of *R. solani* was prepared as follows: two grams of mascerated, dry mycelia was mixed with 100 cc. of water and cooked in the autoclave for 15 minutes at 20 lbs. pressure and then filtered.

Three dilutions of this extract, namely 1%, .5% and .25%, in the nutrient solution described above were prepared, as were also 50%, 25% and 12.5% solutions of the original filtrate. Wheat and turnip seedlings were started in nutrient solution and when well established were transferred to the prepared solutions. The experiment was performed in triplicate and ten seedlings were grown in each culture. After two weeks the seedlings were measured individually. The average heights are given in Table 2.

TABLE 2.—SHOWING THE EFFECT OF DIFFERENT CONCENTRATION OF THE FILTRATE FROM *Rhizoctonia* CULTURES AND OF THE AQUEOUS EXTRACT FROM THE GROUND MYCELIUM ON THE GROWTH OF WHEAT AND TURNIP SEEDLINGS

Concentration	Height of seedlings in cms.						
	Liquid culture filtrate			Mycelium extract			Check nutrient solution
	50%	25%	12.5%	1%	5%	.25%	
Wheat	15 0	15 0	15 0	15 0	15 0	15 0	15 0
Turnips	3 5	6 8	7 0	4 4	4.9	5.5	8 1

From the data it is apparent that the mycelial extract as well as the filtrate from old cultures contains a principle that is toxic towards turnips, but the growth measurements do not reveal any significant effect upon the wheat seedlings.

SUMMARY

Heat sterilized filtrates of old liquid cultures of *Rhizoctonia Solani* Kühn, were markedly toxic towards seedlings of carrots and turnips compared with wheat. Hot water extracts of washed, dried, and ground mycelia were likewise toxic towards turnips but at the concentrations employed in these experiments no evidence of toxicity towards wheat was obtained. This evidence suggests that a heat stable toxin is secreted by *R. Solani* during growth and that it is also present within the mycelia. This toxin may serve to evaluate the relative immunity of plant species and varieties against this fungus for previous studies showed that carrots and turnips were markedly stunted when planted on soils that were artificially infested with the living fungus. Under the same conditions the living fungus had little effect upon wheat.

LITERATURE CITED

1. HAYMAKER, H H. Relation of toxic excretory products from two strains of *F. Lycopersici* to tomato wilt. Jour. Agr. Res. *36* : 697-719. 1928.
2. LISEAU, O. F. On the biology of *Didymella Lycopersici*, the causal organism of the tomato canker disease. Phytopath. Zeitschr. *5* : 1-40. 1932.
3. NEWTON, W. and N. MAYERS. The Physiology of *Rhizoctonia Solani* Kühn. III. The susceptibility of different plants as determined by seedling infection (Preceding paper in this issue).
4. SCHAFFNIT, E. and M. LUDTKE. The formation of toxins by various plant parasites. Ber. deut. botan. Ges. *50* : 444-463. 1932.

Résumé

La physiologie du *Rhizoctonia Solani* Kühn, IV. L'effet sur la végétation du blé, des carottes et des navets d'une substance toxique produite par *Rhizoctonia Solani* Kühn lorsqu'elle est cultivée en culture liquide. W. Newton et N. Mayers, Laboratoire fédéral de pathologie végétale, Saanichton, C.-B.

Des filtrés stérilisés par la chaleur de vieilles cultures liquides de *Rhizoctonia Solani* Kühn, se sont montrés très toxiques sur des plantules de carottes et de navets par comparaison au blé. De même, des extraits à l'eau chaude de mycélia lavés, séchés, et broyés, se sont montrés toxiques envers les navets, tandis qu'aux concentrations employées dans ces expériences aucune preuve de toxicité sur le blé n'a été notée. Cette constatation porte à croire que le *R. Solani* sécrète pendant sa croissance une toxine stable à la chaleur et que cette toxine est également présente dans le mycélium. Elle peut servir à évaluer l'immunité relative des espèces de plantes et des variétés contre ce champignon, car il a été démontré par des recherches précédentes que les carottes et les navets plantés dans des sols qui étaient infestés artificiellement du champignon vivant étaient très rabougris. Dans les mêmes conditions le champignon vivant n'avait que peu d'effet sur le blé.

SOFT ROT OF POTATOES CAUSED BY *PYTHIUM ULTIMUM* TROW[1]

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In October, 1930, a soft rot of potato tubers of the Netted Gem variety was observed on Salt Spring Island, British Columbia, during harvesting of the crop. On casual observation the majority of the diseased tubers appeared almost normal, with the skin intact. When pressed they were soft and resilient and on squeezing a watery liquid oozed out. The internal tissue was broken down and was dirty white to dark in colour, and gave off a fishy smell after exposure to the air. The majority of the affected tubers were not bruised or injured and infection appeared to have taken place initially at the stem ends. A similar condition has since been found on Vancouver Island, and in the Lower Mainland and Interior sections of the Province, indicating that it is widespread.

The disease has also been observed in potatoes stored at high temperatures and under poor ventilation. Under such conditions it spreads rapidly, often resulting in considerable losses. This usually occurs about planting time in spring when day temperatures begin to rise. The mean temperatures for Vancouver Island for fifteen years including 1932, during the months of April, May and June were 47°, 54° and 59° F. respectively.

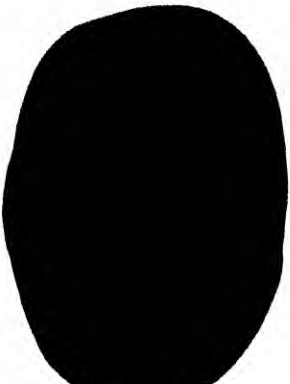

FIGURE 1—Soft rot of Netted Gem potato tuber caused by *Pythium ultimum* Trow.

FIGURE 2—Diseased Netted Gem tuber in section.

Another phase of the disease has recently been found to be associated with the rotting of cut sets in the soil immediately after planting in the spring. During recent years several growers on Vancouver Island and the Mainland have lost considerable acreages in this manner. The rotting of

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the seed has not been known to occur where whole sets were planted. This phase of the disease has been observed in potatoes planted on naturally drained light soils as well as on heavy textured soils. Samples of such soils were taken from the Interior of the province and from Vancouver Island and their pH values ranged from 7 to 8.2.

In some instances the affected sets break down completely appearing as shrivelled pieces in the soil. In others, only portions of the sets become affected. Germination is thus retarded and only weak plants are produced.

Other workers have reported a similar soft rot of potatoes. Thus Hawkins (*1*) has described the symptoms of "leak" disease in potato tubers caused by *Pythium de Baryanum* Hesse, which are similar to those described above for diseased tubers found during harvesting. Also Pethybridge and Smith (*2*) have described the symptoms of a watery wound rot causing serious damage to harvested potatoes. Their description of the disease was also similar to the above. They stated that the causal organism agreed in all essential features with *Pythium de Baryanum* Hesse, with the exception that no zoospores were observed.

Isolation and Pathogenicity

Several isolations have been made from infected tissue representing the different phases of the disease and in all cases *Pythium ultimum* Trow. was isolated.

The pathogenicity of the organism was established by inoculating freshly-cut tubers of the Netted Gem variety with inoculum from a young culture of the fungus and leaving them in a humidity chamber. Cut potato sets were also planted in sterilized soil mixed with a pure culture of the fungus. Positive infection resulted in both instances and the fungus was re-isolated. Whole tubers of the Netted Gem variety were also planted in inoculated soil but no infection was obtained.

When freshly cut sets were planted in inoculated soil in the greenhouse, symptoms of infection generally appeared within forty-eight hours as soft brown areas in the superficial cut tissue. In many of the sets, this infection was confined to the surface areas and germination took place normally. In other sets a considerable portion or all the tissue would be decayed, thus delaying or preventing germination.

Thirty sets of the Irish Cobbler variety were planted in the latter manner and after five days, it was found that fourteen were infected. Several of the diseased sets had developed sprouts and roots at the time of examination.

Five of the latter infected sets, in which the disease was well advanced, were re-planted in individual earthenware pots containing sandy loam soil. These were placed outdoors and after 70 days it was found that two of the sets were completely rotted. Plants had developed from the three other sets. Two of these plants were weak, being much smaller in size than normal. The old sets which had rotted were still attached to them. Similar conditions have often been observed in the field during the growing season. It was also noticed that there were numerous lesions caused by *Rhizoctonia solani* on the stems of these plants. The other plant was more normal in appearance and the attached old set was only partially decayed. On the stems of this plant no lesions caused by *Rhizoctonia solani* were present.

Varietal Susceptibility of Potato Tubers

Ten mature tubers of 15 different varieties were inoculated with the fungus from two day old cultures. Inoculation was done by cutting a section of tissue about 1 cm. deep from each tuber, inserting the inoculum and covering with moistened cotton wool, previously sterilized. The tubers were then kept in humidity chambers.

The varieties tested were Early Ohio, Early Epicure, Early St. George, Bliss Triumph, Irish Cobbler, Early Rose, Earliest of All, Beauty of Hebron, Wisconsin Pride, Gold Coin, Columbia Russet, Up-to-date, Manistee, Rural Russet and Rural New Yorker.

All the varieties proved to be susceptible. None of them exhibited any consistent difference in the degree of susceptibility.

Range of Hosts

Roots of mangels, beets and carrots were inoculated by the same method adopted in the last experiment. All of them proved to be susceptible to infection.

Effect of Temperature on the Growth of the Fungus

The effect of temperature on the growth of the fungus was determined by measuring the diameters of culture colonies grown on potato dextrose solid media at different constant temperatures. The approximate minimum temperature for growth is 4° C., the optimum between 25° and 31° C., and the maximum approximately 40° C.

Effect of Hydrogen Concentration of Culture Media on the Growth of the Fungus

The fungus was grown in petri dishes on potato dextrose agar solid media adjusted to different pH values. There was no growth at pH 2 and 3, and only slight growth when the media was adjusted to pH 3 8, indicating that the minimum pH for growth is between 3 and 4. There was slight growth on the media adjusted to pH 9, indicating that the maximum is above that figure. The optimum pH for growth is between pH 6 and 8.

Effect of Various Treatments of Cut Sets Against Infection

Potato tubers of the Irish Cobbler variety were taken and cut transversely. The different materials enumerated in Table 1 were then applied to the cut surfaces immediately after cutting, the solid materials being first crushed into powder form, and then dusted in even layers on the cut surfaces with a camel's hair brush. In the mercuric chloride paste series, the cut surfaces of the sets were immersed in the paste until even layers were deposited.

Uniform pieces of inoculum from young cultures of the fungus were then placed on the treated and untreated sets. These were kept in humidity chambers and observations on the degree of infection and injury to the tissue were made after four days. The results are given in Table 1.

The mercuric chloride and infusorial earth paste was prepared by adding 100 ccs. of the mercuric chloride solution to 40 grams of powdered infusorial earth and mixing well. These proportions were found to give satisfactory results for immersion. The mercuric chloride-infusorial earth dusts were obtained by drying the paste prepared in the above manner. The concentrations of the mercuric chloride solutions are given for each series in Table 1.

TABLE 1.—THE EFFECT OF TREATING CUT POTATO SETS AGAINST INFECTION BY *Pythium ultimum*

Material	No. of sets treated	No. sets infected after 4 days	Tissue injury due to treatment 0–10
Copper sulphate	10	0	10
Copper sulphate mixed with infusorial earth ratio 50 : 50	10	0	10
Bordeaux dust $CuSO_4$ 16 CaOH 100	10	5	2
Copper carbonate	10	0	2
Copper carbonate mixed with infusorial earth 50 : 50 ratio	10	2	1
Calcium sulphate	10	9	0
Sulphur	20	12	0
Infusorial earth	20	17	0
Mercuric chloride solution 1 : 500	26	0	0
Mercuric chloride solution 1 : 1000	24	6	0
Mercuric chloride infusorial earth dust 1 1000	10	3	0
Mercuric chloride infusorial earth dust 1 : 100	10	0	1
Cut sets dried	10	8	
Cut sets allowed to callus in humid atmosphere at room temperature for 48 hrs.	30	1	
Check—freshly cut sets	20	18	

Analysis of Table 1 shows that there was severe injury of the tubers when treated with copper sulphate, the sets being finally killed. There was also slight injury when Bordeaux dust and copper carbonate were applied. Owing to tissue injury these compounds were discarded for further experimentation.

Soil Infection Studies

In order to find a method of checking infection of tubers in the soil, further work was done. For this purpose sandy loam soil was sterilized, and well mixed with a pure culture of the fungus grown on cooked barley seed. Several infected tubers were also broken up and well mixed with the soil. This inoculated soil was then laid out on a bench in the greenhouse and kept moistened. Mature tubers of the Netted Gem variety were used throughout the experiment. The tubers in each series were cut longitudinally, making two sets for each tuber, each set varying from 2

to 5 oz. Some of the sets were then treated by dusting or by immersion in the pastes and liquids as recorded in Table 2. They were then planted immediately in the inoculated soil. The untreated checks were also planted immediately after cutting. In series 7, the cut sets were placed on moistened peat moss in a humidity chamber in the greenhouse where the temperature ranged between 50° to 85° F. After forty-eight hours they were taken out and planted immediately. An even unbroken callus had been formed by that time. In series 8, the cut sets were left exposed on a bench in the greenhouse for forty-eight hours after which time they were rather soft and shrivelled. They were planted when in that condition.

TABLE 2.—THE EFFECT OF VARIOUS TREATMENTS OF PLANTED CUT POTATO SETS AGAINST INFECTION BY *Pythium ultimum*

Material	Method of treatment	No. of sets	No. of infected sets	Remarks
1. Sulphur	Dusted	20	15	
2. Mercuric chloride solution 1 : 100	Immersion for 5 min.	20	0	Moderate surface injury.
3. Mercuric chloride solution 1 : 500	Immersion for 5 min.	20	6	Slight surface injury.
4. Mercuric chloride solution 1 : 1000	Immersion for 5 min.	20	9	No injury.
5. Mercuric chloride infusorial earth paste 1 : 100	Immersion for 30 sec.	20	6	Moderate surface injury.
6. Mercuric chloride infusorial earth paste 1 : 500	Immersion for 30 sec.	20	6	Slight injury.
7. Cut sets allowed to callus at room temperature in humid atmosphere for 48 hours		20	0	
8. Cut sets allowed to dry out for 48 hrs. at room temperature		20	18	Surface tissue badly contaminated with secondary organisms.
9. Whole tubers		20	0	
10. Check—freshly cut sets.		20	16	

In order to procure further data on the effectiveness of different treatments, potato tubers of the Netted Gem variety were cut transversely into slices of approximately 2 cms. in thickness. Both surfaces of each slice were afterwards treated in the manner described in Table 3. During the twenty-four hour period before planting in series 1, 2, and 3, the slices were left exposed at room temperature in the laboratory. All the slices were planted in infected soil and after four days, observations on the degree of infection were made. By slight infection in Table 3, is meant that only the surface cut tissue was affected, while by severe infection is meant that most of the tissue had broken down.

TABLE 3.—THE EFFECT OF VARIOUS TREATMENTS OF PLANTED POTATO SLICES AGAINST INFECTION BY *Pythium ultimum*

Series	No. of potato slices	Slight infection	Severe infection
1. Dusted with sulphur 24 hours before planting	100	23	1
2. Immersed in mercuric chloride-infusorial earth paste 1 : 500, 24 hrs. before planting	150	11	120
3. Immersed in mercuric chloride solution 1 : 500 for 5 min., 24 hrs. before planting	100	2	80
4. Potato slices allowed to form a callus in humidity chambers at room temperature, 48 hrs. before planting	150	4	5
5. Check—planting done immediately without treatment	70	2	68

Effect of Soil Moisture on Degree of Infection

In order to determine the effect of soil moisture on the incidence of infection, potato slices were cut as in the previous experiment. Some were planted immediately in moist and dry infected soil, while others were allowed to form a callus as in series 4, Table 3, before planting. Observations were made four days after planting and the results are given in Table 4.

TABLE 4.—THE EFFECT OF SOIL MOISTURE ON THE DEGREE OF INFECTION OF POTATO SLICES BY *Pythium ultimum*

		Percentage moisture	No. of potato slices	No. of infected slices
Freshly cut potato slices	Moist	22	50	50
	Dry	8	50	44
Potato slices allowed to form a callus in a humid atmosphere at room temperature for 48 hours	Moist	22	46	5
	Dry	7	45	1

It is evident from the above results that infection of freshly cut sets can take place in very dry soils.

CONCLUSIONS

It is evident from the data presented that the storage temperature for potatoes should be approximately 4° C. or below, since the minimum temperature for the growth of the fungus is approximately 4° C. This is important during the spring months when the disease is known to be present.

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Further analysis of the data shows that the various treatments of cut sets with mercuric chloride are of little value to prevent infection. When the cut sets were dusted with sulphur and planted immediately, there was considerable infection, but when these dusted sets were allowed to dry out at room temperature for twenty-four hours before planting the infection was reduced. In the latter case the sulphur apparently assists tissue suberization, for the sulphur itself is not toxic to the fungus. The cut sets that were allowed to dry out before planting were severely infected and badly contaminated with other secondary organisms. Such sets did not develop any sprouts or roots after planting. Freshly cut sets that were planted in soil containing the fungus, almost invariably became infected. In all the experiments where whole uninjured tubers were planted there was no infection. When cut sets were allowed to form a callus in a humid atmosphere at room temperature for forty-eight hours before planting, infection was reduced greatly. It is evident that of the methods investigated this is the best for treating cut sets before planting to avoid infection. The various chemical treatments are apparently of little use except inasmuch as they may assist in tissue suberization. Priestly and Woffenden (*3*), reporting on the healing of wounds in potato tubers stated that cut sets should be left in a warm, damp and shady atmosphere so as to form a continuous suberized layer, this layer being formed within twenty-four to forty-eight hours. A few days later, cork is formed below this suberin deposit as a result of cell divisions in the cork phellogen layer. They further stated that in a dry atmosphere, especially in sunlight, the suberin layer formed may not be continuous.

It is obvious from this that the principle of proper suberization is important in dealing with cut potato sets that are to be used for planting. This was done quite effectively in the laboratory by laying cut sets on moist peat moss and covering with clean wet bags. These were kept moist by sprinkling with water occasionally. Again, according to Priestly and Woffenden (*3*) "the deposit of fatty suberin layer is formed by oxidation and condensation of fatty substances depositing from the sap drying up in the tissues at the cut surface." It is evident from this that a necessary condition for proper suberization is access to a good supply of oxygen. The cut tubers therefore should have a sufficient supply of air when allowed to callus over in the manner described.

Infection was found when freshly cut sets were planted in moist as well as in very dry soils, but there was a slightly higher percentage of infected sets found in the moist soil. This experiment indicates that when the fungus makes contact with freshly cut tissue, infection may result, regardless of the moisture content of the soil. Fungus growth, however, may be stimulated in soil which is too moist, increasing the chances of infection. In the interior sections of the Province where surface irrigation is practised the soil moisture during planting should be ample for immediate growth of the tubers so as to avoid irrigation immediately after planting.

SUMMARY

1. A soft rot of potato tubers caused by *Pythium ultimum* Trow. is described. It has been found in tubers during harvesting, in storage and also in cut sets after planting in spring.

2. The disease is fairly widespread in British Columbia and is causing considerable losses in some districts, particularly after planting in spring.

3. The pathogenicity of the fungus has been established by direct inoculation on freshly cut tubers and by planting freshly cut tubers in inoculated soil. Infection is very rapid at the optimum temperature for the growth of the fungus. Complete disintegration of the internal tissue may take place within four days under the latter condition.

4. The optimum temperature for the growth of the fungus is between 25° and 31° C. The minimum and maximum temperatures for growth are approximately 4° and 40° C. respectively.

5. The optimum hydrogen ion concentration for the growth of the fungus is between pH 6 and 8. The maximum is above pH 9 and the minimum between pH 3 and 4.

6. The disease susceptibility of fifteen different potato varieties was determined. All of them proved susceptible to infection.

7. The fungus was found to cause disintegration of the roots of mangels, beets and carrots.

8. Whole uninjured tubers did not become infected when planted in soil inoculated with the fungus.

9. Treating cut sets with mercuric chloride solutions and pastes of different concentrations did not effectively check infection.

10. Dusting the cut sets with sulphur and planting immediately in infected soil did not check infection, but when the dusted sets were not planted for twenty-four hours after treatment, the infection was reduced.

11. Cut sets that were allowed to dry out for forty-eight hours before planting, were readily attacked by the fungus as well as by secondary organisms.

12. When cut sets were allowed to form a callus at room temperature in an atmosphere of high humidity for forty-eight hours before planting infection was reduced greatly.

13. Infection of freshly cut sets can take place in wet and very dry soils. There was slightly less infection in a very dry than in a moist soil.

ACKNOWLEDGMENT

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REFERENCES

1. Hawkins, Lon A. Disease of potatoes known as "Leak." Jour. Agric Res *6* : 17 : 627-640. 1916.
2. Pethybridge, G. H. and A. Smith A watery wound rot of the potato. Jour. Min Agric. *37* : 4 : 335-340. 1930.
3. Priestly, J. H. and L. M. Woffenden. Healing of wounds in potato tubers and their propagation. Ann. Appl. Biol. *10* : 96-115. 1923.

Résumé

Pourriture molle des pommes de terre causée par le *Pythium ultimum* Trow.
Walter Jones, Laboratoire fédéral de pathologie végétale, Saanichton, C.-B.

L'auteur décrit une pourriture molle des tubercules de pommes de terre causée par *Pythium ultimum* Trow. Cette pourriture a été trouvée également dans des tubercules au cours de l'arrachage, en cave ainsi que dans les plantons, ou fragments de tubercules, après la plantation, au printemps. Elle est assez répandue en Colombie-Britannique où elle cause des pertes considérables dans certains districts, spécialement après la plantation au printemps. On a établi la pathogénicité du champignon par une inoculation directe sur les tubercules fraîchement coupés et en plantant les tubercules fraîchement coupés dans la terre inoculée. L'infection est très rapide à la température optimum pour la végétation du champignon. Dans ces conditions, une désagrégation complète des tissus de l'intérieur peut se produire en quatre jours. La température optimum pour la végétation du champignon est entre 25° et 31° C. Les températures minimum et maximum pour la végétation sont environ 4° et 40° C., respectivement. La concentration optimum d'hydrogène-ion pour la végétation du champignon est entre pH 6 et 8. Le maximum est supérieur à pH 9 et le minimum est entre pH 3 et 4. La sensibilité à la maladie de quinze variétés différentes de pommes de terre a été déterminée. Toutes ces variétés se sont révélées sensibles à l'infection. Il a été constaté que le champignon cause une désagrégation des racines des betteraves fourragères, des betteraves potagères et des carottes. Les tubercules entiers non endommagés plantés dans un sol inoculé avec le champignon ne se sont pas infectés. Le traitement des plantons avec des solutions de chlorure de mercure et des pâtes de différentes concentrations n'a pas enrayé l'infection d'une façon efficace. Le saupoudrage des plantons avec du soufre et leur plantation immédiate dans une terre infectée n'a pas enrayé l'infection, mais lorsque les plantons saupoudrés n'étaient plantés que vingt-quatre heures après le traitement, l'infection était réduite. Les plantons qu'on laissait sécher quarante-huit heures avant la plantation étaient promptement attaqués par le champignon ainsi que par les organismes secondaires. Lorsqu'on laissait les plantons former un callus à la température de la chambre dans une atmosphère très humide pendant quarante-huit heures avant la plantation, l'infection, était grandement réduite. Les fragments fraîchement coupés peuvent s'infecter dans des sols humides et très secs. Il y avait un peu moins d'infection dans un sol très sec que dans un sol humide.

INVESTIGATIONS ON THE BLACK KNOT OF PLUMS AND CHERRIES

III. SYMPTOMATOLOGY, LIFE HISTORY, AND CULTURAL STUDIES OF *DIBOTRYON MORBOSUM* (SCH.) T. and S.[1]

L. W. Koch[2]

INTRODUCTION

Black knot is undoubtedly the most destructive fungous disease attacking plums in North America and though common on sour cherries is usually less severe. In Ontario the injury caused by this fungus varies considerably from year to year both as to host and locality. In the Niagara peninsula where spraying and pruning are commonly practised and where relatively few wild hosts are present black knot is not as serious a factor in the growing of plums and cherries as it is in the Georgian Bay and certain other districts.

Certain phases of the present investigations on black knot have been reported in previous articles (*9*), (*10*), and while the articles III and IV submit the results of the remaining fundamental phases of the problem they also include a general summary of all findings, thereby completing the report of the results of the investigations to date.

REVIEW OF LITERATURE

Only literature relevant to those phases of the problem considered in the present article will be dealt with here. The early investigators of this disease, *e.g.*, Peck (*12*), Farlow (*5*), Halsted (*6*), Beach (*1*), etc., contributed largely to our present day knowledge of the symptomatology of black knot. Since that time numerous brief popular articles have appeared all of which deal chiefly with symptomatology and suggestions for control, but none of these has added to our knowledge of symptomatology. In a recent article (*9*) dealing with the present investigations it was demonstrated that the pink areas which appear consistently in July and August every year on the conidial stroma of the knot are caused by *Cephalothecium roseum* Corda. It was proved that the latter organism actively parasitizes the stroma of the black knot pathogen and by destroying the perithecial initials exerts an important measure of biologic control over the knot pathogen. Certain other fungi were also found to be constantly associated with knots and to alter the normal development of perithecia on the knots during the winter. Concerning the life history of the causal organism and other fundamental phases of the problem, contributions have remained few in number. Heald (7) in 1934 states that "with our present information there are several blanks in the life history of the pathogen, the part played by the different spore forms and the exact time and manner of infection being based on observational data." During the course of the present investigations (*9*) it has been reported that "over a period of four years the initial ascospore discharge from perithecia of *D. morbosum* on *Prunus domestica* L. in the Niagara peninsula varied from March 23 to

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April 6, after which discharges occurred periodically until June 6 or 7." Under laboratory conditions perithecia from the same host discharged ascospores as early as November 20 in 1931.

Regarding the life history of the pathogen reports have been both confusing and contradictory. No investigator has successfully determined the life history of *D. morbosum* by the germination of monoascospores in pure culture or by infection experiments on the host. Farlow (*5*) in 1876 described three types of pycnidia which he found mingled with perithecia. At least one of these, namely *Hendersonula morbosa* Sacc., has been proved (*10*) to be not genetically connected with *D. morbosum*. Later Humphrey (*8*) in 1891 stated that he obtained a single-celled, brown-spored pycnidial form from ascospores. Undoubtedly this fungus was the *Coniothyrium* sp. which was shown in a previous article (*10*) to be an organism distinct from the black knot pathogen though closely associated with it throughout all but the most incipient stages of its life history. The *Coniothyrium* sp. is also saprophytic on buds and bark of various fruit trees. Stevens (*16*) in 1925 assigned the conidial stage of the black knot pathogen to the genus *Cladosporium*.

There is no literature dealing with the study of *D. morbosum* in artificial culture.

SYMPTOMATOLOGY

Though the outstanding symptoms of black knot are familiar to the majority of phytopathologists, certain of them must be discussed here because of the inadequate and in part incorrect symptomatological picture prevailing in text-books.

Black knot is first manifested as a small swelling on a twig or branch either at the border of a knot already formed or separate from it. In the case of primary infections, swellings nearly always appear during the fall of the year of infection. During the following spring all knots become much larger in size, the bark ruptures and during June the surface of the gall-like excrescence becomes covered with a velvety-green pad of fungous tissue. During midsummer pink and white areas caused by *Cephalothecium roseum* and other fungi (see Review of Literature) frequently appear on the green conidial stroma of many knots. During late summer and early fall the green pad of mycelium disappears and is replaced by black stromatal tissue from beneath. By late fall most knots are perfectly black. During the winter perithecia of *D. morbosum* mature on the surface of the knots and ascospores are discharged during April and May.

The opinion regarding the first appearance and subsequent development of knots has been that in most cases knots do not become conspicuous until the spring following infection. Even though there are records of the appearance of small swellings in the fall of the year of infection no conidia have been observed until the following year. These observations have given rise to the opinion universally expressed in text books, namely, that two years is required for *D. morbosum* to complete its life cycle on the host. However, the present investigations have proved that this is not always true. Observations made during the fall and spring of three consecutive years proved that at least 93% of all knots are visible as swellings during the fall of the season of infection, while the remaining 7% were doubtful.

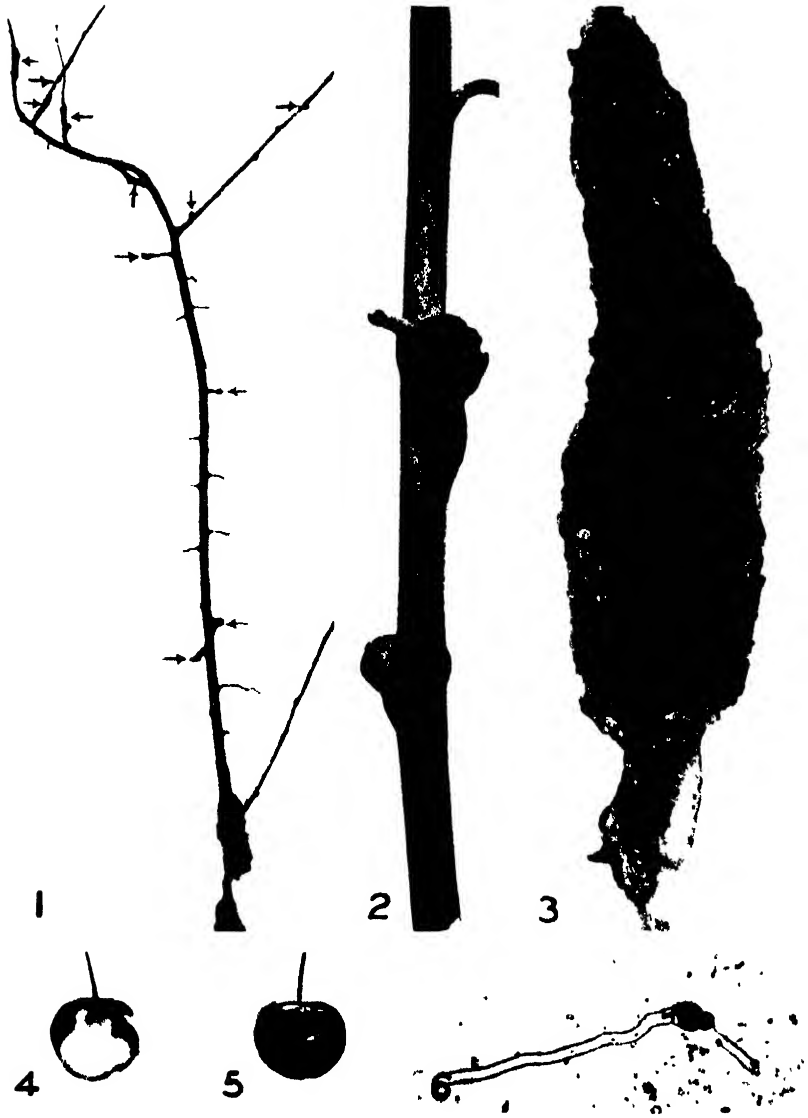

PLATE I. 1. Branch of *P. domestica* one and one-half years old showing numerous tiny knots on current season twigs. Photo taken 12 9 32. 2. Current season twigs with knots already producing conidia. Photo taken 25 8 32. 3. Mature black knot producing perithecia of *D. morbosum*. Photo taken 24 4 33. 4. *Hormodendrum* sp. (strain C) growing on sour cherry fruits. 5. As in 4, strain X. 6. Photomicrograph of germinating ascospore of *D. morbosum*. This ascospore developed into conidial colony, strain Z, × 300.

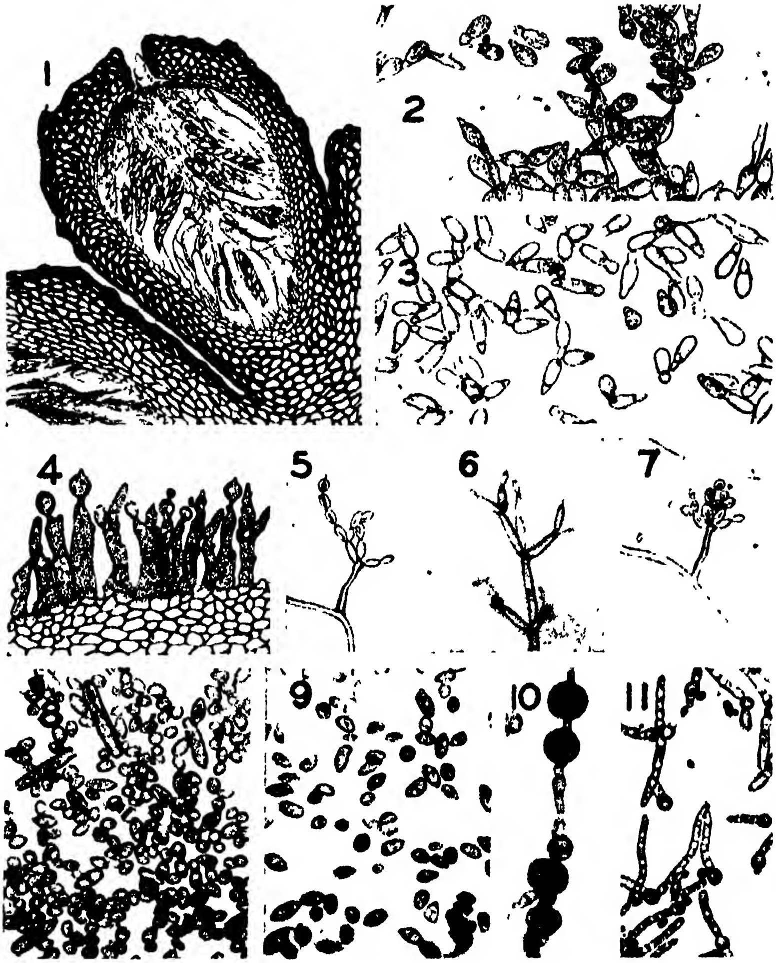

PLATE II, Life history of *D morbosum* 1. and 4 Drawings, 2, 3 and 5-11, Photomicrographs. 1. Mature perithecium of *D morbosum*, × 140 2 Ascospores of *D morbosum* from knot on *P. pennsylvanica*, × 300 3 As in 2, from knot on *P domestica*, × 300 Note difference in shape of spores in 2 and 3. 4 Conidial stage on host, × 500 5-7. Various types of conidiophores and conidia (*Hormodendrum* sp) in culture, × 300 8 Conidia of *Hormodendrum* sp (strain Z) from 7-day old culture, × 300 9 As in 8 (strain C). 10 Chlamydospores of *D. morbosum*, × 300 11 Conidia of *Hormodendrum* sp (strain X) germinating, × 300

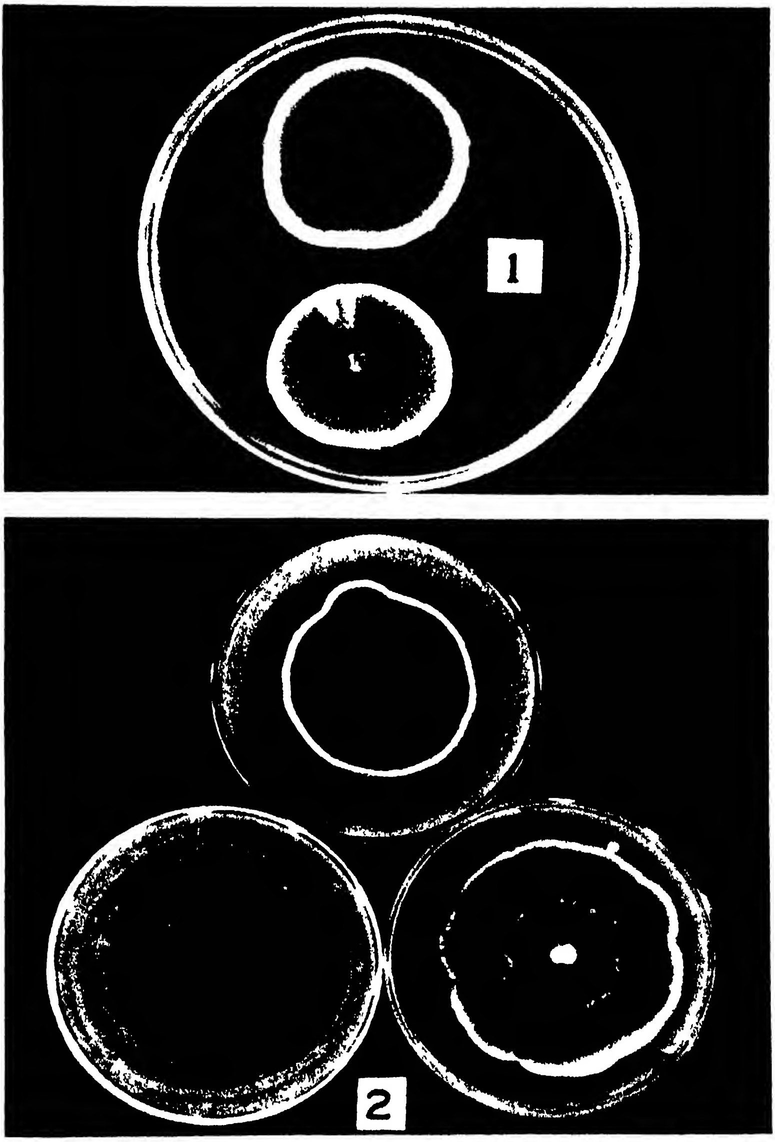

PLATE III. Petri dish colonies of conidial (*Hormodendrum*) strains of *D. morbosum* growing on potato 2½ per cent dextrose agar. 1. (colonies 33 days old at 5-7° C.) (Upper, strain Z, Lower, strain X. 2. (Colonies 19 days old at 22-24° C.) Upper, strain Y; Lower left, strain Z, Lower right, strain X. Three strains in 2 all isolated from monoascospores obtained from a single knot.

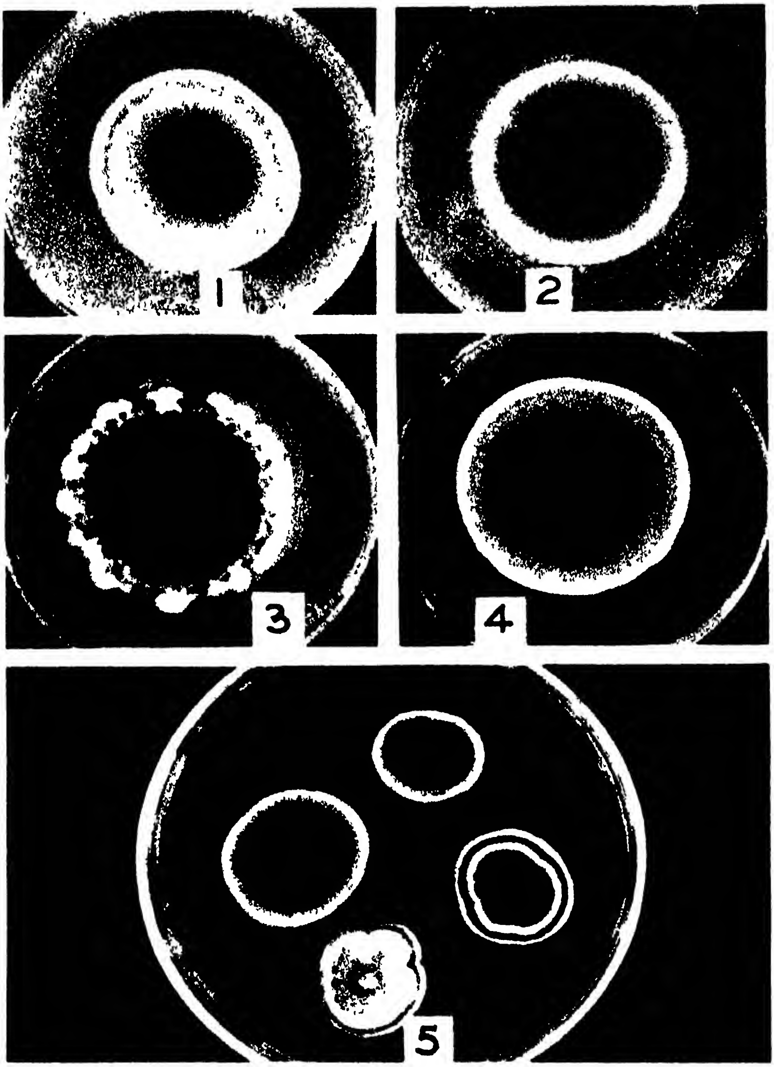

PLATE IV Four conidial (*Hormodendrum*) strains isolated from monoascospores of *D. morbosum* 1-4 Colonies 11 days old growing on potato 2½ per cent dextrose agar at 27-28° C. 1 Strain C. 2 Strain Y. 3. Strain X. 4 Strain Z 5. Colonies 33 days old growing on potato agar at 8-10° C. Upper, strain Z; Middle left, strain X, Middle right, strain Y; Lower, strain C.

Of these knots which were visible during the fall, a proportion, which varied greatly from year to year, always produced conidia during August and September of the year of infection (Plate I, 2). Usually the area producing conidia was small but even so is capable of producing a large number of spores. On the conidial-bearing stromata of these knots perithecia developed in many instances during the subsequent winter and spring, thereby completing the life cycle of the fungus within one year.

The general opinion that wood of any age is susceptible to primary infection has not been substantiated by the present investigations. A survey conducted during three consecutive years revealed that in a plum orchard containing numerous varieties 95% of all newly-formed knots originated on current-season twigs, 1% originated on branches more than one year old, 1 % on relatively fresh pruning stubs and the remaining 3% were of doubtful origin. The remarkable feature of the survey was, however, the preponderance of knots originating on current-season twigs (Plate I, 1). During the course of the survey numerous knots were observed on the large branches and in some cases on the trunks themselves, but continuous observations of numerous tagged knots proved that in practically all cases the invasion of the trunk could be traced to infection through a small lateral.

Smaller twigs when infected were frequently killed within a year after infection but because of the localized effect of the parasite, larger branches usually resisted the attack of the fungus for several years before succumbing. In June and July, during which months most of the hypertrophy of the host occurred many of the smaller twigs and branches wilted suddenly, due to the complete interruption of the water supply by the knot.

TAXONOMY

The pathogen which causes black knot was first named *Sphaeria morbosa* by Schweinitz (*15*) in 1821. Other generic names have been suggested since that time but without general acceptance. Saccardo (*14*) assigned the organism to the Dothideales and called it *Plowrightia morbosa* (Sch.) Sacc ; Plowright (*13*) thought it belonged in the genus *Gibbera;* Ellis (*3*) called it *Cucurbitaria morbosa* (Sch.) Ell., and soon afterwards Cooke (*2*) called it *Othiella morbosa* (Sch.) Sacc. Ellis and Everhart (*4*) in 1890 adopted Cooke's nomenclature and termed it *Othiella morbosa,* claiming that the genus *Plowrightia* in Sacc. Syll. is unsatisfactory, including as it does, species with true perithecia, such as *Sphaeria morbosa* (Sch.) and others with mere ascigerous cells, such as *Dothidea ribesia,* (Pers.) the latter being a genuine *Dothidea.*

Plowrightia morbosa appears to have been used more widely than any other name in referring to the pathogen. However, in recent years there has been some uncertainty as to the correct taxonomic position of this fungus. Thiessen and Sydow (*18*) in 1918 placed the fungus in their newly-proposed order the Pseudosphaeriales and named it *Dibotryon morbosum* (Sch.) T. and S. In 1921 Sorauer (*17*) transferred the genus *Plowrightia* Sacc. to *Botryosphaeria* and named the black knot fungus *Botryosphaeria morbosa* (Sch.) Sor.

The perithecia of the pathogen in question have individual perithecia with distinct walls (Plate II, 1) and do not at all resemble those of the

type species *Plowrightia ribesia* (Pers.) Sacc. where the perithecia are reduced to polyascous loculi. The fungus cannot, therefore, be placed in the genus *Plowrightia* Sacc., which, in any case is a synonym of *Dothidella* Speg. On the other hand, the fungus is not typically a sphaeriaceous one but rather Pseudosphaeriaceous in character. It would, therefore, be most advisable to call it *Dibotryon morbosum* (Sch.) T. and S. though it is still questionable whether or not Thiessen and Sydow (*18*) were justified in ranking the Pseudosphaeriales as a separate order.

LIFE HISTORY STUDIES

Investigations concerning the life history of the fungus causing black knot were conducted to obtain information concerning (1) the characters of the perfect stage and (2) the correct imperfect stage or stages. In the case of the latter, as explained previously, numerous and widely-different imperfect stages have been reported for *D. morbosum* none of which has been proved experimentally.

Material was collected from scattered localities throughout Ontario, and specimens were also obtained from Manitoba, Quebec and Nova Scotia. This material was utilized without special preparation and in most cases sections were cut with a sliding microtome after which they were stained in cotton blue and mounted in lacto-phenol for examination.

Perithecial Stage

D. morbosum was observed to be constantly associated with knots collected during the winter, though there are marked variations in the abundance of its perithecia on different knots even on the same tree. Mature ascospores can usually be found as early as February on *Prunus domestica* in Ontario though they apparently do not begin discharging ascospores in the Niagara peninsula until late in March or early in April (*9*). Examinations of the perithecia and ascospores showed that they corresponded in detail with Saccardo's (*14*) description of *Plowrightia morbosa*.

Isolations from the Perithecial Stage

Using material from the localities mentioned above, numerous isolations were made from the perithecial stage of *D. morbosum*. Pure suspensions of ascospores were obtained by the method described in a previous article (*9*). Loopfuls of these suspensions were streaked over the surface of Petri dishes containing potato 2 5% dextrose agar or other solid media. In this way all ascospores were in the same plane and could be examined when desired.

To obtain information regarding germination, the suspensions of ascospores were subjected to various conditions of temperature and moisture before plating. In all, 142 isolants were obtained from perithecia of *D. morbosum*, 48 of which were monosporous in origin. From all monoascosporous cultures a species of *Hormodendrum* developed. There were, however, four apparently distinct strains designated X, Y, Z and C (Plates III and IV) which will be dealt with in detail later.

It should be mentioned in connection with the above isolations that great difficulty was experienced in obtaining ascospores which would both germinate and complete their development to an imperfect stage. After

48 to 96 hours in distilled water the ascospores of *D. morbosum* frequently produced germ tubes of considerable length, in accordance with illustrations and statements by previous investigators (*5*, *7*), but in most cases their development ceased at that point. It was discovered that ascospores germinated only when discharged from fully mature perithecia. Frequently it was necessary to allow the spores to germinate and remain in distilled or tap water for 3 to 5 days before plating them in order that some of them might continue growth. In a few cases ascospores which were allowed to remain in a thin film of water for a week continued development and produced conidia after very little mycelial development. Low temperatures of 7-12° C. for the above-mentioned period prior to plating also frequently improved the percentage germination. Provided the ascospores were mature an increase of 50% in the oxygen of the atmosphere surrounding the thin film of water containing the ascospore suspension improved to some extent both the germination and further development of the ascospores.

Close examinations and measurements of ascospores revealed the existence of a relation between size of ascospores and host, worthy of mention. The lengths and widths of 388 ascospores (in a water suspension) from knots on each of the hosts *Prunus pennsylvanica* and *P. domestica* were taken and the percentages of the total number of ascospores of each size unit were calculated. The latter are shown graphically in Figure 1. It will be observed in the graph that the ascospores from knots on *P. pennsylvanica* are both longer and wider than those from knots on *P. domestica*. While the modes for the length and width of the ascospores on the former host lie at 17 to 18, and 7 respectively, for ascospores on the latter host the modes lie at 16 and 6 respectively. The difference in size

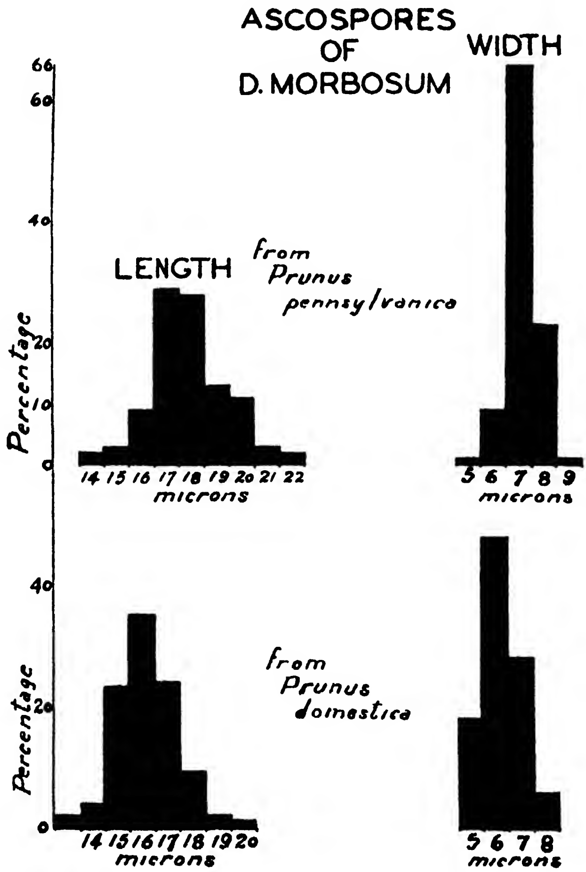

FIGURE 1—Graph illustrating distribution curves of sizes of ascospores of *D. morbosum* from *Prunus pennsylvanica* and from *P. domestica*.

and shape of ascospores from knots on these two hosts is illustrated in Plate II, 2 and 3.

During the investigations involving the germination of ascospores certain interesting cultures were obtained in April, 1933. On three occasions from monoascospores of *D. morbosum* and on eight other occasions from a suspension of supposedly-pure ascospores, conidial cultures were obtained which resembled the *Hormodendrum* stage of *D. morbosum* in every respect except that both mycelium and spores were hyaline, and the mycelium was somewhat less in diameter and less vigorous than that of the *Hormodendrum*. The colonies themselves were pure white on potato dextrose agar and invariably with age and repeated transfers they ceased to produce conidia. It would seem highly suggestive that these cultures were saltants from the parent, in which loss of colour resulted during reduction division in the formation of the ascospores.

Conidial Stage

As stated above in the Review of Literature numerous conidial stages have in the past been reported for *D. morbosum*. During the present investigation, however, in two instances germinating ascospores were photographed at intervals of two hours during the initial stages and up to eight hours during their later development until they finally developed conidia typical of *Hormodendrum* 68 to 74 hours later (Plate I, 6).

In addition to the latter proof that *Hormodendrum* is the imperfect stage of *D. morbosum*, reference to the pathogenicity studies in article IV will show that in several instances inoculations with either ascospores of *D. morbosum* or conidia of *Hormodendrum* sp. resulted in the development of knots, some of which produced a *Hormodendrum* conidial stage followed by perithecia belonging to *D. morbosum*.

Summing up the foregoing evidence we find definite proof of the genetic connection of *Hormodendrum* sp. and *D. morbosum*.

Mention should be made of the difference in morphology of the conidial stage of *D. morbosum* on its host and in culture. On its host conidia are produced superficially on green pads of stroma. Conidiophores are shorter and much more flexuose than in culture, being erect, septate, usually simple and ranging in size from 20–65 × 4–6 microns (Plate II, 4). Conidia are borne singly, usually at the apex of the conidiophore, obovate, unicellular, light olivaceous brown and 4–8 × 2–5 microns in size.

On the other hand, in culture conidiophores of the pathogen vary tremendously in length (Plate II, 5–7), frequently being more than 100 microns in length, and long dendroid chains of conidia develop at the apex. Conidia varied in size from 3–20 × 2–5.5 microns (Plate II, 8 and 9).

When portions of the conidial-bearing stroma of a knot were brought indoors and placed in moist Petri dishes a certain number of the conidiophores increased in length and developed chains of spores very similar to those produced on artificial media. No doubt, wind and lack of moisture play an important role in the morphology of the fungus outdoors on the host.

Isolations from the conidial stage

Monosporous cultures were made from *Hormodendrum* conidia, employing the same methods as were used for the ascospores. These were made both from *Hormodendrum* conidia in cultures which originated from ascospores and from conidia which developed on the fruiting surface of knots in nature during June. In every case colonies of *Hormodendrum* sp. developed which were similar in every respect to those originating from ascospores. The same four strains which developed from ascospores appeared frequently in these cultures. Frequently three of these four strains were isolated from a single knot on either *Prunus domestica*, *P. cerasus* or *P. pennsylvanica*. Two additional strains appeared on several occasions from conidia but since certain saprophytic species of both *Hormodendrum* and *Cladosporium* were also frequently isolated from the conidial fruiting surfaces of knots these strains were not intensively investigated.

Isolations from Swollen Tissues Adjacent to Knots

More than 600 isolations were made from swollen tissues adjacent to knots and from apparently normal tissues nearby. In these isolations a species of *Coniothyrium* frequently appeared, in addition to the *Hormodendrum* sp. This *Coniothyrium* sp. has been discussed in a previous article (*10*) and has been definitely proved not to belong genetically to *D. morbosum*. During the more recent investigations in which young knots were detected when they appeared as only very faint swellings on infected twigs (Plate I, 1) at which time infections could not have been more than 4 months old, it was found that only *Hormodendrum* sp. appeared in the isolations, provided epidermal tissues were removed prior to placing the tissues on media. It was frequently difficult to isolate the knot fungus from infected tissues even though it was known to be present. Occasionally when plugs of infected tissue were placed on artificial media, the host tissue continued to become hypertrophied and the fungus produced first a conidial stroma bearing a few conidia on the plug of tissue and later immature perithecia. On no occasion, however, were these cultures induced to complete their development to the production of mature perithecia containing mature ascospores of *D. morbosum*.

Chlamydosporous Stage

In addition to a perithecial stage, *D. morbosum*, and a conidial stage, *Hormodendrum* sp., the black knot pathogen was proved in a previous article (*11*) to produce a chlamydosporous stage (Plate II, 10) under certain conditions. The interesting discovery was made that *D. morbosum* produced chlamydospores only when grown in close proximity to certain other organisms, or when chemicals were introduced into the culture medium. Chlamydospore formation was also induced on twigs of *Prunus domestica* when *Hormodendrum* conidia germinated in intimate association with antagonistic bacteria originally isolated from the same host.

CULTURAL STUDIES

Since the conidial or *Hormodendrum* stage is the actively parasitic one throughout most of the growing season its growth reaction in pure culture to various temperatures and to different culture media was studied.

TABLE 1.—SOURCES OF ISOLATION AND DISTINGUISHING FEATURES ON CERTAIN MEDIA OF FOUR CONIDIAL (HORMODENDRUM) STRAINS OF *D. morbosum*

Strain	Source of isolation	Distinguishing features		
		On potato 2½% dextrose agar	On Czapek's synthetic agar	On sterile, sour cherry fruits
X	(1) Monoascospores from knots on *Prunus domestica* and *P. pennsylvanica*. (2) Incipient knot swellings. (3) Conidia on knots produced both naturally and artificially.	Margin of colony indented and very irregular. Narrow white border. Zonation. Under side of colony dark. Upper surface of colony, dark greenish olive.*	As on p.d.a.	Very dark green, sparse mycelium, short conidiophores.
Y	(1) Monoascospores as in X. (2) Incipient knot swellings. (3) Conidia on knots outdoors.	Margin of colony regular. Wide white border. Under side of colony light yellow, sometimes pigmenting the medium. Upper surface of colony, dull citrine.*	As on p.d.a.	
Z	(1) Monoascospores as in X. (2) Incipient knot swellings. (3) Conidia on knots produced both naturally and artificially.	More aerial mycelium than X or Y Under side of colony frequently pinkish, sometimes pigmenting medium. Usually producing sectors. Zonation. Upper surface of colony, deep olive.*	Less aerial mycelium than on p.d.a.	
C	(1) Monoascospores as in X. (2) Incipient knot swellings on *P. domestica* and *P. cerasus*. (3) Condia on knots outdoors.	Abundance of aerial mycelium. Long conidiophores. Conidia less abundant than in X, Y or Z. Upper surface of colony, deep olive gray.*	Very dark in colour with with white border. Aerial mycelium not as abundant as on p.d.a.	Light olive gray,* abundance of aerial mycelium, Conidiophores long and sparse.

*According to Colour Standards and Colour Nomenclature by Ridgway.

Comparisons of the growth characteristics of the four strains of *Hormodendrum* mentioned previously are given in Table 1. Colonies from which descriptions were made were 7 days old and were growing in Petri dishes containing 10 cc. media at 22–23° C.

It will be observed from an examination of this table that these four strains were distinguished both by their colour and growth reactions on certain media (Plates III and IV). On certain other media, *e.g.*, plum decoction and Leonian's malt the four strains also proved to be distinguishable but not as readily as on the media tabulated.

Cultures were also grown at the following temperatures:—5–7° C., 8–10° C., 10–12° C., 31–32° C.

The relative growth rates of four conidial strains namely X, Y, Z and C at three different temperatures on potato 2.5% dextrose agar are shown in Figure 2 where the maximum diameter of the colony growing in 10 cc. media on a Petri dish in each case has been plotted against the length of the growth period. Growth occurred throughout the unusually wide temperature range 3–33° C. It will be observed in the graph that 7–9° C. was evidently below the optimum, while the highest temperature 31–32° C. was above it. At 22–24° C. growth was rapid and steadily maintained for all strains. Strain Z grew more rapidly at all temperatures and had a somewhat wider range than any of the other three strains. A marked parallelism in relative growth rates of the four strains was observed at different temperatures. The rapidity of growth was in nearly all cases in the order X, Y, Z

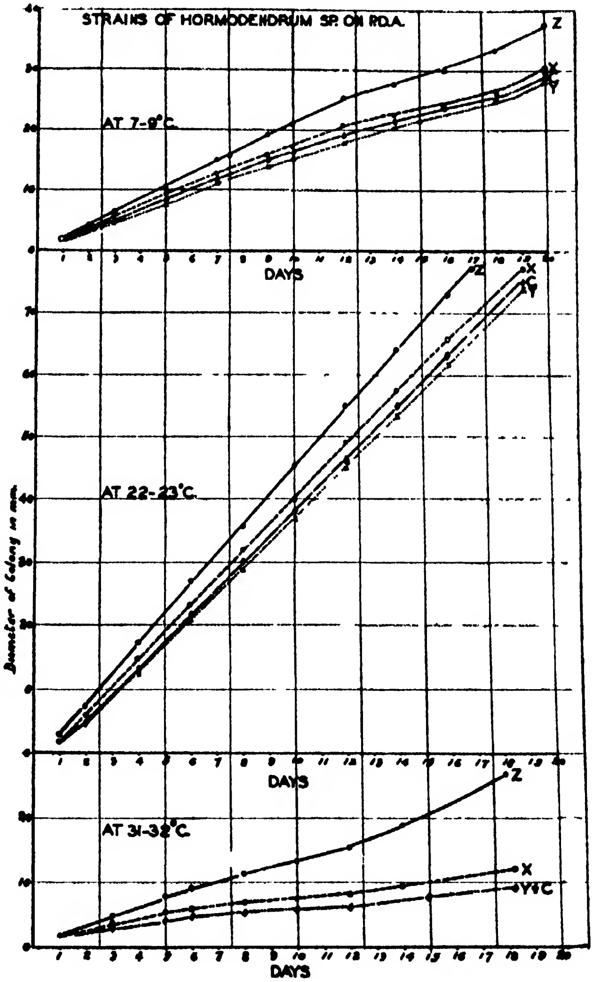

FIGURE 2. Graph illustrating the relative growth rates of 4 conidial strains (*Hormodendrum* sp.) of *D. morbosum* on potato 2½ per cent dextrose agar at 3 different constant temperatures.

and C respectively, though in several cases (*e.g.* 31–32° C.) the growth rate of Y and C fell along practically the same line.

It will be observed from the above that the strains X, Y, Z and C can in nearly all cases be distinguished by their relative growth rates at the same and at different temperatures. Another outstanding feature of the above experiments was the ability of all four strains of *Hormodendrum* to grow at relatively low temperatures. It seems probable from these experiments that *D. morbosum* is active at considerably lower temperatures than are favourable for the growth of its host.

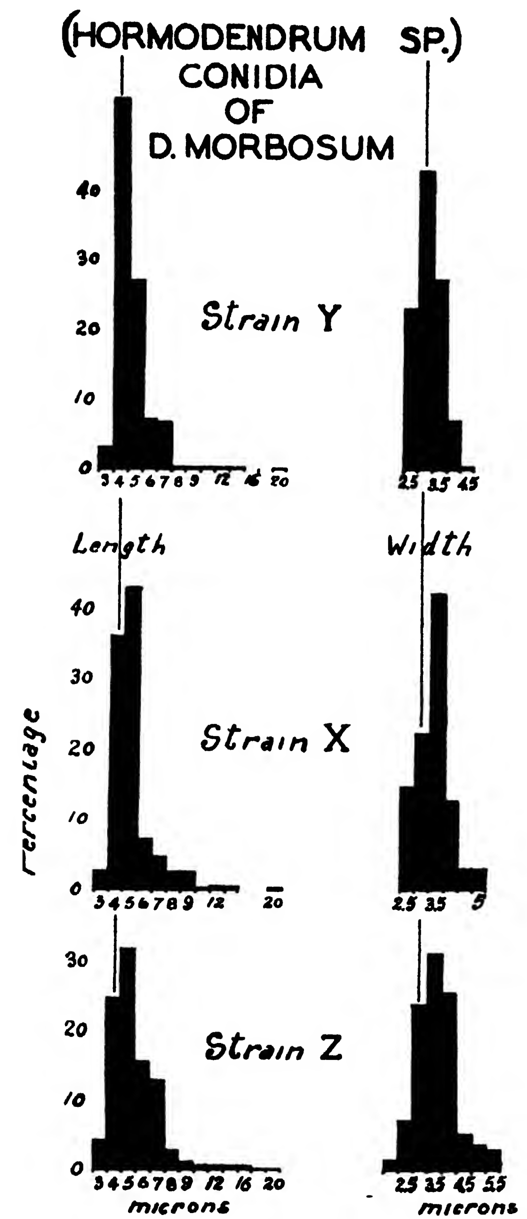

FIGURE 3.--Graph illustrating distribution curves of sizes of spores of 3 conidial (*Hormodendrum*) strains of *D. morbosum.*

All four of the above-mentioned conidial strains have been cultured and sub-cultured many times. Generally speaking, no changes were observed in them even after sub-culturing them for several years. Strain Z was observed to produce sectors consistently and frequently, while sectors were produced by other strains relatively infrequently. Curiously enough, the sectors produced by strain Z always appeared to be identical. After sub-culturing numerous of these "sector" colonies for a period of 6 months or more, occasionally one reverted to what appeared to be the parent strain, but, generally speaking, the sector apparently remained as it was when first transferred.

Conidia of all strains were stained with Haidenhain's iron-alum haematoxylin and were found to vary from a single to multinucleate condition. The majority of the conidia of strain Z, however, appeared to be multinucleate while on the other hand the majority of conidia belonging to strains Y, X and C appeared to uninucleate. It therefore seemed possible that some relation existed between the nuclear condition of strain Z and its habit of sectoring.

A relatively small proportion of conidia of all strains germinated on potato dextrose agar at room temperature in 12 to 24 hours (Plate II, 11) while in distilled water very little germination occurred. After several days in distilled water some free budding of conidia occurred and occasionally a few conidia produced germ tubes and a small amount of mycelium.

In an attempt to distinguish strains by their respective spore sizes, measurements were made of 256 conidia of the three *Hormodendrum* strains isolated most frequently, namely X, Y and Z and the percentages of conidia occupying each size unit was calculated. These comparative percentages are illustrated graphically in Figure 3. It will be observed from an examination of this graph that the modes for the length and width of conidia of strain Y lie at 4 and 3 microns respectively, while similar modes for conidia of each of the other two strains X and Z lie at 5 and 3.5 microns respectively. While the modes for both length and width of conidia of strains X and Z lie at the same points strain Z possesses a larger percentage of both longer and wider conidia than strain X which approximates the former most closely in size.

Thus from the above we conclude that the conidia of strain Y are smaller both in length and width than the conidia of either strain X or strain Z. On the other hand strains X and Z cannot be as easily distinguished by the size of their conidia though there is more variability in strain Z than in strain X.

DISCUSSION

The present investigation has yielded new and additional information regarding the symptomatology of the black knot disease and the life history of the causal organism. Many of the observations recorded by the earlier investigators of black knot, particularly those relating to symptomatology though never confirmed have been accepted unquestioned, and as a consequence are found even in the latest text books.

The discovery that more than 95% of primary black knot infection occurs on current season twigs alters the conception formerly held, namely, that branches of all ages are infected. It also suggests a high type of parasitism on the part of the pathogen. Nearly all knots resulting from spring infection were detected in the fall of the same year as small swellings on the twigs. Some of these incipient knots produced an abundance of conidia during the fall of the year of infection and perithecia during the following winter, thereby completing the life cycle of the pathogen on the host within a year. Thus, contrary to prevailing opinion, *D. morbosum* in so far as it is capable of completing its life cycle within a year on the host does not differ from *Venturia inaequalis* and many other Ascomycetes parasitic on fruit trees.

At first sight it seems surprising that the knowledge of the life history of a pathogen as widespread and as destructive as *D. morbosum* has remained so long incomplete and that no contributions in this connection have appeared in the last twenty years. However, there are extenuating circumstances to account for the hindrance to the solution of the problem.

When ordinary cultural technique is employed only rarely do ascospores continue development beyond the formation of germ tubes. Furthermore, numerous other fungi are always found associated with black knots, except those in incipient stages. Finally, there is considerable difficulty in obtaining successful artificial infection. The conidial stage, though it commonly develops on young knots, has never previously been identified as a species of *Hormodendrum* because it has never been critically studied in culture. As it appears on the host the conidial stage cannot be definitely assigned to any genus because its true characteristics rarely, if ever, appear as it is exposed to wind and rain both of which tend to remove the majority of conidia as soon as they mature and consequently the conidiophores never become dendroid, nor do the conidia develop in long chains as they invariably do in culture.

During the present investigations the history of two ascospores of *D. morbosum* has been followed by means of photomicrographs from the initial stages of germination to the final formation of *Hormodendrum* conidia 68 to 74 hours later. The chlamydosporous stage of *D. morbosum* has proved interesting not only because the chlamydospores were found capable of remaining viable throughout the winter but also because they were produced in culture only in the presence of certain other organisms or of chemicals. The isolation of four morphologically distinct conidial strains of *Hormodendrum* sp. from monoascospores of *D. morbosum* indicates a resemblance in this respect to numerous other fungi in which more than one morphologically distinct conidial strain has been demonstrated. These strains suggest the occurrence of physiological forms.

REFERENCES

1. Beach, S. A. Black knot of plum and cherry. N.Y. (Geneva) Agr. Exp. Sta. Bull. 40 : 25-34. 1892.
2. Cooke, M. C. Grevillea 15, 84. 1882.
3. Ellis, J. B. North American Flora. p. 691. 1881.
4. ———, and Everhart, B.M. The North American Pyrenomycetes. p. 251. 1892.
5. Farlow, W. G. Black knot. Bull. Bussey Inst. *24* : 440-453. 1876.
6. Halsted, B. D. Destroy the black knot of plum and cherry. An appeal. N.J. Agr. Exp. Sta. Bull. *78* : 1-14. 1891.
7. Heald, F. D. Manual of Plant Diseases. McGraw Hill Book Co. Inc. 1933.
8. Humphrey, J. E. The black knot of the plum. Mass. (Hatch) Agr. Exp. Sta. Bull. Reprt. *8* · 235-238. 1893.
9. Koch, L. W. Investigations on black knot of plums and cherries I. Development and discharge of spores and experiments in control. Sci. Agr. *13* : 576-590. 1933.
10. ———. Investigations on black knot of plums and cherries II. The occurrence and significance of certain fungi found in association with *D. morbosum.* (Sch.) T. and S. Sci. Agr. *15* : 80-95. 1934.
11. ———. Studies on the overwintering of certain fungi parasitic and saprophytic on fruit trees. Can. Jour. Research *11* : 190-206. 1934.
12. Peck, G. H. Trans. Albany Inst. *7* : 186-204. 1872.
13. Plowright, C. B. Some remarks upon *Sphaeria morbosa.* Monthly Microscopical Journal. May, 1875.
14. Saccardo, P. A. Sylloge Fungorum. *2* : 638. 1883.

15. SCHWEINITZ, A. DE. Sphaeria morbosa. Synopsis Fungorum Corolinae superioris 134. 1821.

16. STEVENS, F. L. Plant Disease Fungi. The Macmillan Co. p. 156. 1925.

17. SORAUER, PAUL. Handbuch der Pflanzenkrankheiten, *2* : 328-329. 1921

18. THIESSEN, F. and SYDOW, H. Vorentwurfe zu den Pseudosphaeriales. Ann Myc. *16* : 1-34. 1918.

Résumé

Recherches sur le "Black Knot" ou nœud noir du prunier et du cerisier, III. Symptomatologie, cycle évolutif et culture du *Dibotryon morbosum* (Sch.) T. & S. L. W. Koch, Laboratoire fédéral de pathologie végétale, St. Catharines, Ont.

Contrairement à l'opinion que l'on entretenait jusqu'ici, il a été démontré que le *Dibotryon morbosum* peut compléter son cycle évolutif dans le cours d'une année et que la majorité des infections primaires prennent naissance sur les rameaux de la saison. Des observations minutieuses et des photomicrographies d'ascospores à germination unique, dont la majorité produisent des tubes germinatifs et ne continuent pas à se développer, ont démontré pour la première fois que la phase imparfaite du *D. morbosum* est de l'espèce *Hormodendrum*. Une phase de Chlamydospore s'est également développée en certaines occasions. La phase conidiale sur l'hôte diffère de celle de la culture. Quatre espèces conidiales distinctes l'une de l'autre au point de vue morphologique (*Hormodendrum*) ont été isolées des monoascospores du *D. morbosum*.

STUDIES ON THE PHYSIOLOGY OF THE OAT SMUTS[1]

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Ustilago avenae (Pers.) Jens. and *U. levis* (K. and S.) Magn., the two fungi causing smut of oats, occur in every important oat growing region of the world, and are frequently responsible for serious reductions in yield. These two species may be distinguished from each other by the appearance of their spores, those of *U. avenae* being echinulate, whereas those of *U. levis* are smooth. It is also usually considered that they produce different effects on their host-plants. Thus, *U. avenae* may cause rather complete destruction of the floral parts of its host, giving rise to the disease known as "loose smut." The sori of *U. levis*, however, may be entirely concealed by the glumes, a condition known as "covered smut."

Under field conditions considerable difficulty may be experienced in distinguishing these two species from each other by the manner in which they attack oat panicles. Frequently it is found that heads of the "covered" type contain echinulate spores, and sometimes heads of the "loose" type may contain smooth spores. Such observations appear to throw some doubt upon the value of the spore-wall markings, and the relationship between them and the appearance of the diseased panicles, as reliable specific characters. To obtain further information on these points experiments with pure cultures of the two oat smuts were begun at this laboratory in 1929. A preliminary report (*6*) on this investigation was published in 1930.

EXPERIMENTAL METHODS

Single chlamydospores of *U. avenae* and *U. levis* collected on Longfellow oats were germinated in hanging drops of Difco potato-dextrose-agar, and their sporidia were removed and cultured separately, according to the method described by Hanna (*4*). The temperature of germination was kept between 18° and 20° C. The position on the promycelium occupied by each sporidium was noted, and the four monosporidial cultures obtained from each promycelium were designated accordingly. When a monosporidial culture in a hanging drop had reached a diameter of about 3 mm., it was transferred to a test tube of potato-dextrose-agar. Using this method, the four sporidia from each of 10 chlamydospores of *U. avenae* and 13 chlamydospores of *U. levis* were removed and cultured separately.

Dehulled seeds of Longfellow and Abundance oats were treated with formalin and germinated on moist filter-paper. Some lots of these seedlings were inoculated with single monosporidial cultures of *U. avenae*, others with single monosporidial cultures of *U. levis*, and others with pairs of cultures of *U. avenae* or of *U. levis*. Other inoculations were made by mating a single monosporidial culture of *U. avenae* with one of *U. levis*. The seedlings were inoculated when their coleoptiles were about 5 mm. or less in length. The method of inoculation was to rub some of the sporidia

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on the surface of the coleoptile, after which the seedling was kept on moist filter-paper or sand until the first leaf had formed. It was then transplanted, and grown to maturity either in the greenhouse or in the field. The panicles of the mature plants were examined for smut infection, and notes were taken on the appearance of the smutted heads and on the kind of spores found in them.

Pathogenicity of Monosporidial Cultures Used Singly and in Pairs

Plants grown from seedlings inoculated with a single monosporidial culture of either species showed no sign of infection and failed to produce smutted heads. This conclusion is based on the results of inoculations made with 114 single monosporidial cultures.

Forty-six cultures of *U. avenae* and 58 cultures of *U. levis* were used in making the inoculations with paired monosporidial cultures. The *U. avenae* cultures originated from complete sets of four sporidia isolated from each of 10 chlamydospores, and sets of three sporidia isolated from each of 2 chlamydospores. The *U. levis* cultures originated similarly from all four sporidia from each of 13 chlamydospores, and sets of three sporidia from each of 2 chlamydospores. Plants grown from seedlings inoculated with certain pairs of monosporidial cultures of *U. avenae*, or of *U. levis*, or with certain monosporidial cultures of *U. avenae* paired with certain others of *U. levis* produced smutted heads, whereas plants grown from seedlings inoculated with other such pairs of cultures did not. Hence, it was concluded that the monosporidial cultures belonged to two different sexual groups, and that smutted heads were produced only by those plants which had been inoculated with two monosporidial cultures of opposite sex. On this basis, each set of monosporidial cultures originating from a single chlamydospore could be divided into two sexual groups, designated as (+) and (−). Furthermore, as monosporidial cultures originating from different chlamydospores, whether of *U. avenae* or of *U. levis*, mated with one another in the same ratio as did those from a single chlamydospore, it was concluded that the same two sexual groups were present in both species.

Distribution of Sporidia of Diverse Sex on the Promycelium

Other investigators (*2*), (*5*), (*7*), have shown that in the genus *Ustilago* the distribution of sporidia of different sexes on the promycelium is determined at the time of reduction-division. If reduction occurs at the first division of the fusion-nucleus the arrangement of the nuclei and sporidia will be as follows: (++−−), or (−−++); if at the second division: (+−+−), (−+−+), (+−−+), or (−++−). In the present investigation the distribution of the sporidia of different sexes on the promycelium was determined by inoculation experiments for 10 chlamydospores of *U. avenae* and 13 of *U. levis*. In addition, sets of three sporidia were removed from the promycelia of 2 other spores of each species and, after the sex to which these sporidia belonged had been determined, it was possible to establish by inference the sex of all four sporidia from each spore. In 4 spores of *U. avenae* and 3 of *U. levis* it was concluded that reduction of the factors for sex occurred at the first division of the fusion-nucleus, and in 8 spores of *U. avenae* and in 12 of *U. levis* at the second

division. Thus, in 7 of the spores reduction occurred at the first nuclear division, and in 20 at the second division. It is possible that different results might have been obtained had these spores been germinated on other media or at a higher or lower temperature. Bauch's (*1*) experiments with *U. longissima* indicate that relatively high temperatures favour reduction at the first division; and Dickinson (*3*) has shown that the time of segregation may be affected by the hydrogen-ion concentration of the medium, the temperature of germination, and the total concentration and relative proportions of carbohydrate and nitrogen in the medium.

The Inheritance of Spore Characters

Plants inoculated with two monosporidial cultures of opposite sex of *U. avenae* produced echinulate chlamydospores, and those inoculated with a pair of such cultures of *U. levis* produced smooth chlamydospores. The appearance of the spore-wall, therefore, may be regarded as a reliable character for differentiating the two species.

When plants were inoculated with a monosporidial culture of *U. avenae* and one of opposite sex of *U. levis*, the hybrid-chlamydospores formed in the smutted heads were echinulate, and identical in appearance with those of the *U. avenae* parent. There is every reason to believe that this cross occurs frequently under natural conditions, in which case the hybrid-chlamydospores would be mistaken for chlamydospores of *U. avenae*. Holton (*7*) obtained the same results in his inoculation experiments with pure cultures of the oat smuts.

Considerable difficulty was experienced in culturing the single sporidia from germinated hybrid-chlamydospores resulting from crosses between *U. avenae* and *U. levis*. However, a few such cultures were obtained, and 10 of them were used in inoculation-experiments to determine the manner in which sex and spore-wall character are inherited. Nine of the pairings made between certain of these cultures gave rise to echinulate chlamydospores, and 7 gave rise to smooth chlamydospores. Back-crosses made between certain of the hybrid-cultures and cultures of *U. levis* yielded 4 combinations which produced echinulate chlamydospores and 7 which produced smooth chlamydospores. Similar back-crosses were made with *U. avenae* and, of the 6 fertile combinations obtained, all produced echinulate chlamydospores. Summarizing the results of all the matings, it is concluded that 4 of the 10 hybrid cultures were (+) in reaction and carried the factor for smooth spore-wall, whereas the remaining 6 were (−) in reaction, 4 of them carrying the factor for echinulate spore-wall and 2 the factor for smooth spore-wall. These data show also that the factor for echinulate spore-wall is dominant over that for smooth spore-wall.

The Inheritance of Type of Smutted Head

In a preliminary report of this investigation (*6*) it was stated that plants inoculated with two cultures of opposite sex of *U. levis* produced heads of the "covered" type, whereas plants inoculated with similar cultures of *U. avenae*, or with a culture of *U. avenae* and one of opposite sex of *U. levis* produced heads of the "loose" type. This conclusion was based on the results of inoculations made in the greenhouse. Since then many

TABLE 1.—THE RELATION BETWEEN THE KIND OF CHLAMYDOSPORES PRODUCED ON OATS INOCULATED WITH PAIRS OF MONOSPORIDIAL CULTURES AND THE APPEARANCE OF THE INFECTED HEADS

Chlamydospores	Kind of chlamydo-spores	Total number of heads	Number of "covered" heads	Number of "loose" heads	Number of powdery heads	Percentage of "covered" heads	Percent-age of "loose" heads	Percentage of powdery heads
Grown in the Greenhouse								
Ustilago avenae	Echinulate	405	146	259	346	36.0	64.0	85.4
U. levis	Smooth	305	258	47	9	84.6	15.4	3.0
F_1 (*U. avenae* × *U. levis*)	Echinulate	284	150	134	224	52.8	47.2	78.9
F_2 (*U. avenae* × *U. levis*)	Smooth	77	42	35	1	54.5	45.5	1.3
F_2 (*U. avenae* × *U. levis*)	Echinulate	49	15	34	32	30.6	69.4	65.3
F_1 (*U. avenae* × *U. levis*) × *U. levis*	Smooth	47	22	25	4	46.8	53.2	8.5
F_1 (*U. avenae* × *U. levis*) × *U. levis*	Echinulate	33	17	16	11	51.5	48.5	33.3
Grown in the Field								
U. avenae	Echinulate	39	22	17	39	56.4	43.6	100.0
U. levis	Smooth	66	66	0	10	100.0	0	15.2
F_1 (*U. avenae* × *U. levis*)	Echinulate	140	101	39	140	72.1	27.9	100.0

more inoculated plants have been grown both in the greenhouse and in the field, and somewhat different results have been obtained. It is now apparent that the classification of heads into "loose" and "covered" types is much more difficult than the classification of spores on the basis of spore-wall character. Furthermore, the character of the spore-wall cannot always be predicted from the appearance of the heads in which the spores are borne. The nature of the spore-wall seems to be determined solely by the genetic constitution of the parasite. In the experiments made thus far, it has proved to be independent of the variety of the host-plant and the conditions of growth. The appearance of the infected head, however, probably results from the interaction of parasite, host, and the conditions under which the latter is grown. Under field conditions, as is shown in Table 1, plants inoculated with cultures bearing the factor for smooth spore produce a much higher proportion of heads of the "covered" type than do those inoculated with cultures bearing the factor for echinulate spore. Yet, in plants inoculated with similar cultures and grown in the greenhouse, the differences are much less marked. Apparently, therefore, the inherent capacity of the parasite to affect its host in a particular way may be modified by environmental conditions. Some extreme variations in the appearance of infected heads are shown in Figures 1 and 2.

The results of these experiments are not in complete agreement with those of Holton (7) who states: "Artificial inoculations with crosses between monosporidial lines of *Ustilago avenae* produced both the loose and covered smuts. *Ustilago levis* produced only the covered smut. Crosses between *U. avenae* and *U. levis*, produced loose, covered, and intergrading types of smut."

The nature of the spore-mass, whether "powdery" or otherwise, determines the extent to which, under field-conditions, the spores will be dispersed by the wind. Notes were taken, therefore, on the consistency of the spore-masses in the infected heads. If the chlamydospores fell out readily when the heads were tapped against a sheet of white paper, the heads were classified as "powdery." This classification of the heads is included in Table 1. If "looseness" is considered to result not in the more or less complete destruction of the glumes, but in the production of sori containing powdery masses of spores, then it is evident from the data presented that cultures bearing the factor for echinulate spore usually produce a much higher proportion of heads of the "loose" type than do those bearing the factor for smooth spore.

Spore Germination and Sporidial Growth

Chlamydospores of different collections of *U. avenae*, *U. levis*, and the hybrid (*U. avenae* $\times$ *U. levis*) have been tested for germination and, although differences were found in the germinability of individual collections of spores, it was not apparent that spores of the parent species differed from one another or from the hybrid in their ability to germinate. The percentage germination of different kinds of chlamydospores is given in Table 2.

The pathogenicity of F_1 hybrid-chlamydospores was compared with that of the two parent species by dusting oat-seed with the three kinds

FIGURE 1. Extremes of variation in the appearance of smutted oat panicles produced on plants inoculated with pairs of monosporidial cultures. Left, two heads of "loose" smut (*Ustilago avenae*), right, two heads of the "loose" type produced by *U. levis*.

FIGURE 2. Extremes of variation in the appearance of smutted oat panicles produced on plants inoculated with pairs of monosporidial cultures. Left, two heads of the "covered" type produced by *Ustilago avenae*, right, two heads of "covered" smut (*U. levis*).

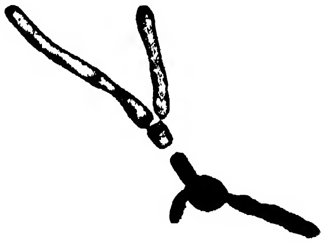

FIGURE 3. Photomicrograph of an F_1 hybrid (*Ustilago avenae* × *U. levis*) chlamydospore which has germinated but failed to develop further. × 800

TABLE 2.—THE GERMINATION OF INDIVIDUAL OAT SMUT CHLAMYDOSPORES AND THE GROWTH OF THEIR SPORIDIA IN HANGING DROPS OF POTATO-DEXTROSE-AGAR

Chlamydospores	Kind of chlamydospores	Number placed to germinate	Number germinating	Percentage germination	Number producing colonies of sporidia	Percentage producing colonies of sporidia
Ustilago avenae	Echinulate	236	144	61 0	52	36 1
U levis	Smooth	1033	642	62 1	410	63 9
F^1 (*U. avenae* × *U. levis*)	Echinulate	542	337	62 2	31	9 2
F^2 (*U. avenae* × *U. levis*)	Smooth	60	42	70 0	31	73 8
F^2 (*U. avenae* × *U. levis*)	Echinulate	178	90	50 6	62	68.9
F^1 (*U. avenae* × *U. levis*) × *U. levis*	Smooth	208	130	62 5	76	58 5
F^1 (*U. avenae* × *U levis*) × *U. levis*	Echinulate	140	91	65 0	67	73 6

of spores and sowing it in pots in the greenhouse. Sixty-nine per cent of the plants grown from seed inoculated with the F_1 spores were smutted, as compared with 94 and 90% respectively for the plants grown from seed inoculated with spores of the *U. avenae* and *U. levis* parents. It may be concluded, therefore, that considerable numbers of sporidia or hyphae from the F_1 hybrid-chlamydospores are capable of combining sexually and infecting young oat-seedlings.

In studying the germination of F_1 hybrid-chlamydospores it was noticed that, although the spores germinated normally, many of their sporidia were unable to continue growth on artificial media. The sporidia of these spores either failed to grow, or elongated slightly into short hyphae which subsequently died. This condition is illustrated in Figure 3. The relative ability of different kinds of chlamydospores to form colonies of sporidia or hyphae when germinated separately in hanging drops of potato-dextrose-agar is shown in Table 2. Relatively few of the F_1 hybrid-chlamydospores succeeded in producing colonies as compared with those of *U. avenae* or *U. levis* It is also significant that the F_2 (*U. avenae* × *U. levis*), and the F_1 (*U. avenae* × *U. levis*) × *U. levis* chlamydospores formed colonies as readily as did those of *U. avenae* or *U. levis*. This would seem to indicate that the factor affecting the growth of the sporidia of F_1 hybrid-chlamydospores was not operating in the F_2 hybrid-chlamydospores and in those produced by back-crossing the F_1 hybrid with the *U. levis* parent.

In other experiments individual sporidia were removed from germinating chlamydospores of *U. levis* and of the F_1 hybrid (*U. avenae* × *U. levis*) and were placed in hanging drops of nutrient-medium. The subsequent development of these sporidia was then observed. Some of them multiplied and produced colonies, but others failed to grow. The results of the experiments have been summarized in Table 3. In this table the two parent monosporidial cultures of each collection of chlamydospores are given, and the sporidia isolated from different kinds of chlamydospores have been considered separately. The subscript attached to the number designating each parent monosporidial culture refers to the position of the sporidium on the promycelium, and the number or letter preceding it to the chlamydospore from which the sporidium came. Thus, $2BO_1$,

$2BO_2$, $2BO_3$, and $2BO_4$, refer to cultures of the 1st, 2nd, 3rd, and 4th sporidia of spore 2BO, the sporidia being numbered from the apex of the promycelium to the spore.

TABLE 3.—THE GROWTH ON NUTRIENT-AGAR OF INDIVIDUAL SPORIDIA REMOVED FROM GERMINATING CHLAMYDOSPORES OF *Ustilago levis* AND OF THE F_1 HYBRID (*U. avenae* × *U. levis*)

Parent monosporidial cultures of the chlamydospores	No. of sporidia isolated	No. of sporidia which grew	Per cent of sporidia which grew
(*U. levis* × *U. levis*)			
$2BO_1 \times 2BO_2$	54	24	44
$2BO_1 \times 2BO_4$	11	11	100
$2BO_2 \times 2BO_3$	64	26	41
$2BO_3 \times 2BO_4$	22	22	100
$2B3_3 \times 2B3_4$	51	51	100
$2B3_1 \times 2B3_4$	22	22	100
$2BJ_1 \times 2BJ_2$	12	12	100
$2BJ_1 \times 2BJ_3$	21	19	90
Total	257	187	73
(*U. avenae* × *U. levis*)			
$D1_3 \times G2_1$	100	0	0
$D1_1 \times G2_3$	36	0	0
$D1_2 \times G2_3$	76	4	5
$D1_1 \times G2_4$	48	1	2
$D1_2 \times G2_4$	100	10	10
Total	360	15	4

From the data given in Table 3 it would appear that the sporidia of certain collections of chlamydospores of *U. levis* are more difficult to culture than those of others, and that between collections of the F_1 hybrid-chlamydospores the variability in this respect is still more pronounced. Of the 360 individual sporidia isolated from F_1 hybrid-chlamydospores, only 4 per cent continued growth and formed colonies, whereas of 257 sporidia similarly isolated from spores of *U. levis*, 73 per cent formed colonies. Complete sets of four sporidia were removed from numbers of germinating F_1 hybrid-chlamydospores, but in no instance did all four continue growth and produce colonies. The greatest number of monosporidial cultures obtained from a single one of these spores was two, and frequently all four sporidia from a hybrid-spore failed to grow. Yet, no such difficulty was experienced in culturing all four sporidia from individual chlamydospores of *U. avenae* or *U. levis*. Apparently many sporidia of the F_1 hybrid-chlamydospores are unsuited physiologically to propagate themselves on nutrient-media. This peculiarity may be due to inability of the chromosomes of the two parent species to mate completely with one another. Holton (7) experienced the same difficulty in making monosporidial cultures from F_1 hybrid-chlamydospores.

In making monosporidial cultures from a collection of chlamydospores of *U. levis* it was observed that the growth produced by certain sporidia

TABLE 4.—SEGREGATION FOR SPORIDIAL AND HYPHAL TYPES OF GROWTH IN GERMINATING CHLAMYDOSPORES OF *Ustilago levis* PRODUCED BY MATING SPORIDIAL AND HYPHAL TYPES OF MONOSPORIDIAL CULTURES DERIVED FROM A SINGLE CHLAMYDOSPORE.

Chlamydospores from the cross: hyphal colony No. 2 (−) × hyphal colony No. 3 (+)				Chlamydospores from the cross: sporidial colony No. 1 (+) × sporidial colony No. 4 (−)				Chlamydospores from the cross: sporidial colony No. 4 (−) × hyphal colony No. 3 (+)				Chlamydospores from the cross: sporidial colony No. 1 (+) × hyphal colony No. 2 (−)			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
H	H	H	H	S	S	S	S	H	S	H	S	H	S	H	S
H	H	H	H	S	S	S	S	S	H	H	S	H	S	H	S
H	H	H	H	S	S	S	=	S	H	H	S	O	O	S	H
H	O	H	O					S	S	H	H	O	O	S	H
O	H	O	H					*	H	=	*	H	O	O	S
H	O	O	H					=	*	H	H	O	O	S	S
H	H	O	O									O	H	O	H
O	H	H	O									S	H	O	O
*	*	H	H									O	S	S	O
O	O	O	O									=	H	S	=
O	O	O	O									O	O	O	O
O	O	O	O									O	O	O	O
O	O	O	O									O	O	O	O
O	O	O	O									O	O	O	O
O	O	O	O												
O	O	O	O												

NOTE: Numbers 1, 2, 3, and 4 indicate position of sporidia on promycelium, numbering from the apex to the base. The following symbols have been used: (H), for hyphal colony. (S), for sporidial colony. (*), for a colony composed of hyphae and sporidia. (=), for sporidia which were not isolated. (O), for sporidia which were isolated and failed to grow.

in hanging-drop cultures of potato-dextrose-agar consisted entirely of hyphae, whereas that produced by others consisted of sporidia. These two types of growth could be distinguished under the microscope one or two days after the sporidia had been removed from the promycelium, but later when the cultures had been transferred to test-tubes, the differences between them disappeared and all tended to produce hyphae. Cultures from one of these chlamydospores were used to inoculate oat-seedlings. In making the incoulations sporidia of opposite sex were paired together so that the following combinations of cultural types were secured: (sporidial × sporidial,) (hyphal × hyphal), and (sporidial × hyphal). Chlamydospores resulting from these crosses were then germinated singly and their sporidia were removed and cultured separately in hanging drops of potato-dextrose-agar. The types of colonies produced by sporidia from the three kinds of chlamydospores are listed in Table 4. It will be seen that three of the chlamydospores yielded sporidia producing intermediate types of colonies composed of both sporidia and hyphae. With these exceptions, however, the chlamydospores resulting from the crosses (sporidial × sporidial) and (hyphal × hyphal) produced on germination only sporidial and hyphal types of colonies respectively, while chlamydospores resulting from the cross (sporidial × hyphal) produced the two colony-types in the ratio of 2 sporidial to 2 hyphal on each promycelium. The distribution of the two kinds of sporidia on the promycelium indicates that segregation for cultural type may take place at the first or second division of the chlamydospore-nucleus. Dickinson (*3*) and Holton (*7*), working with *U. levis*, and with *U. avenae* and *U. levis* respectively, have also found that segregation of certain cultural characters may occur at the first or second nuclear division. It is of interest that all four sporidia from certain promycelia failed to produce colonies, and that of other sets of four sporidia only two survived. Even more important is the fact that in none of the groups of four did only a single sporidium grow. This suggests that the capacity of the sporidia to reproduce on artificial media is a heritable character, independent of sex and cultural type.

SUMMARY

1. The sporidia were removed from the promycelia of individual germinating chlamydospores of *Ustilago avenae* and *U. levis*, and cultured separately on nutrient-agar. Oat-seedlings inoculated with these cultures were grown to maturity.

2. Plants inoculated with single monosporidial cultures of *U. avenae* or *U. levis* failed to produce smutted heads.

3. Plants inoculated with two monosporidial cultures of opposite sex of *U. avenae* or *U. levis*, or with a culture of *U. avenae* and one of opposite sex of *U. levis* produced smutted heads.

4. Heads infected with *U. avenae* or with the hybrid (*U. avenae* × *U. levis*) contained echinulate chlamydospores; those infected with *U. levis* contained smooth chlamydospores. Proof of the dominance of the factor for echinulate spore over that for smooth spore was obtained by back-crossing cultures of the F_1 hybrid (*U. avenae* × *U. levis*) with cultures of *U. avenae* and *U. levis*.

5. The appearance of smutted heads, whether "covered" or "loose," is not always a reliable indication of the kind of chlamydospores which they contain. However, plants inoculated with cultures bearing the factor for echinulate spore produce a higher proportion of heads of the "loose" type than do those inoculated with cultures bearing the factor for smooth spore. There is evidence that the appearance of smutted heads is determined by the conditions under which the plants are grown as well as by the genetic constitution of the smut-fungus attacking them.

6. The sporidia of *U. avenae*, like those of *U. levis*, are of two kinds, (+) and (−); the sporidia of the one species mate without difficulty with sexually opposite sporidia of the other species.

7. Segregation for sex and cultural characters (sporidial and hyphal types of colonies) was found to occur at either the first or the second division of the chlamydospore-nucleus.

8. No significant difference was found in the ability of *U. avenae*, *U. levis*, F_1 (*U. avenae* × *U. levis*), F_2 (*U. avenae* × *U. levis*) and F_1 (*U. avenae* × *U. levis*) × *U. levis* spores to germinate, but sporidia of the F_1 (*U. avenae* × *U. levis*) spores, as compared with those of the others, are much less capable of growth on artificial media.

REFERENCES

1. Bauch, R. Multipolare Sexualitat bei Brandpilzen. Zeitschr. f. induktive Abstammungs- und Vererbungslehre. *54* : 258-259. 1930.
2. Dickinson, S. Experiments on the physiology and genetics of the smut fungi. Cultural characters. Part I.—Their permanence and segregation. Proc. Roy. Soc. London, Ser. B. *103* : 547-555. 1928.
3. ——— ———. Experiments on the physiology and genetics of the smut fungi. Cultural characters. Part II.—The effect of certain external conditions on their segregation. Proc. Roy. Soc. London, Ser. B. *108* : 395-423. 1931.
4. Hanna, W. F. A simple apparatus for isolating single spores. Phytopath. *18* : 1017-1021. 1928.
5. ——— ———. Studies in the physiology and cytology of *Ustilago zeae* and *Sorosporium reilianum*. Phytopath. *19* : 415-442. 1929.
6. ———, and W. Popp. Relationship of the oat smuts. Nature *126* : 843-844. 1930.
7. Holton, C. S. Studies in the genetics and the cytology of *Ustilago avenae* and *Ustilago levis*. Minn. Agr. Expt. Sta. Tech. Bull. 87. 1932.

Résumé

Etudes sur la physiologie du charbon de l'avoine. W. Popp et W. F. Hanna, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

Les sporidies ont été enlevées des promycelia de chlamydospores de *Ustilago avenae* et *U. levis* en germination, et cultivées séparément sur agar nutritif. Des plantules d'avoine inoculées de ces cultures ont été développées jusqu'à maturité. Les plants inoculés d'une seule culture monosporidiale de *U. avenae* ou *U. levis* n'ont pas réussi à produire des épis charbonnés. Les plants inoculés avec deux cultures monosporidiales de sexe opposé de *U. avenae* ou *U. levis* ou avec une culture de *U. avenae* et une du sexe opposé de *U. levis* ont produit des épis charbonnés. Les épis

infectés avec *U. avenae* ou avec l'hybride (*U. avenae* x *U. levis*) contenaient des chlamydospores échinulées; ceux qui étaient inoculés avec *U. levis* contenaient des chlamydospores lisses. On a obtenu une preuve de la dominance du caractère pour les spores échinulées par comparaison à celui des spores lisses, en recroisant les cultures de l'hybride F_1 (*U. avenae* x *U. levis*) avec des cultures de *U. avenae* et *U. levis*. L'apparence des épis charbonnés, "vêtus" ou "non vêtus", n'est pas toujours une indication positive du genre de chlamydospores qu'ils renferment. Quoi qu'il en soit, les plants inoculés avec des cultures portant les caractères pour les spores échinulées produisent une plus forte proportion d'épis du genre "nu" ou "non vêtu" que ne font ceux qui sont inoculés avec des cultures portant le caractère pour les spores lisses. Il y a des preuves que l'apparence d'épis charbonnés est réglée par les conditions dans lesquelles les plants sont cultivés aussi bien que par la constitution génétique du champignon du charbon qui les attaque. Les sporidies de *U. avenae*, de même que celles de *U. levis* sont de deux espèces, (+) et (−); les sporidies d'une espèce s'accouplent sans difficulté avec les sporidies du sexe opposé de l'autre espèce. On a constaté que la ségrégation pour les caractères de sexe et de culture (types de colonies sporidiales et hyphales) se produit à la première ou la deuxième division du nucléus-chlamydospore. Aucune différence significative n'a été constatée dans l'aptitude germinative des spores de *U. avenae*, *U. levis*, F_1 (*U. avenae* x *U. levis*), F_2 (*U. avenae* x *U. levis*) et F_1 (*U. avenae* x *U. levis*) x *U. levis*, mais les sporidies des spores de F_1 (*U. avenae* x *U. levis*) comparées à celles des autres, sont beaucoup moins susceptibles de développement sur milieu artificiel.

ABSTRACTS[1]

INOCULATION STUDIES IN PEACH CANKER. R. S. Willison, Dominion Laboratory of Plant Pathology, St. Catharines, Ontario.

Two distinct species of the genus *Valsa* have been isolated from peach cankers in Ontario and identified as *V. leucostoma* (Pers.) Fr., and *V. cincta* Fr., respectively. The salient differences between these fungi, both in culture and on the host, are briefly discussed.

Monosporous cultures of these two species and of *Sclerotinia americana* (Worm.) Nort. and Ez., were used in series of inoculations, made at intervals of one to four weeks over a period of two years, by means of wounds approximately one-and-one-half by one-half inch, cut in branches previously sterilized by brushing with a 1 to 500 solution of mercuric chloride and washing with distilled water. In order to obtain conditions as natural as possible, the wounds were left exposed to the weather without wrapping of any sort. All wounds were measured periodically to determine the amount and rate of healing or enlargement.

In all series, the history of wounds inoculated with *V. leucostoma* closely approximated that of comparable non-inoculated check wounds.

S. americana produced more or less necrosis during the first two or three weeks after inoculation in those series made during the growing season, but little or none in those made during the winter months. Subsequent to the initial damage, healing progressed steadily except in a few wounds which became naturally contaminated with *Valsa* sp. (in most cases *V. cincta*).

On the other hand, *V. cincta*, in series made during the dormant season and for four or five weeks preceding leaf fall, produced cankers which showed either continuous increase in size or increase alternating with a certain amount of healing. Maximum necrosis was caused by this organism when infection occurred at or about leaf-fall. Inoculations made during the summer months with *V. cincta* were comparatively innocuous.

THE CONTROL OF BROWN HEART IN TURNIPS. D. J. MacLeod and J. L. Howatt, Dominion Laboratory of Plant Pathology, Fredericton, New Brunswick.

Brown heart, described by Hurst (Report of Dominion Botanist for 1929, pp. 216–221), is an important limiting factor in the production of turnips in Eastern Canada. In view of the failure to discover a parasitic origin for this obscure trouble, the authors turned to the hypothesis that a mineral deficiency might be the cause. Field tests revealed that sodium tetraborate (borax) applied directly in the drill at the rate of 10 pounds per acre effected a satisfactory control of this disorder and slightly increased the yield. The efficiency of the borax treatment was not materially affected when applications were made in combination with chemical fertilizer, barnyard manure, sulphur, ground limestone or hydrated lime. At the time of emergence there was a slight marginal chlorosis of the leaves of plants receiving the borax treatment. This condition, however, disappeared after from 10 to 14 days. In a limited number of tests, kelp, barnyard manure and sulphur at the rate of 20 and 40 tons and 1,000 pounds per acre, respectively, also controlled the brown heart, but less efficiently than the borax. Sodium chloride at the rate of 400 pounds per acre increased the disorder.

MAGNESIUM DEFICIENCY IN POTATOES. D. J. MacLeod and J. L. Howatt, Dominion Laboratory of Plant Pathology, Fredericton, New Brunswick.

A condition serving as a limiting factor in potato production in New Brunswick has been under observation for two years. This disorder resembles that described by Chucka (Amer. Pot. Jour. *11* : 29-35. 1934) and Knoblauch and Odland (*Ibid.*

[1] Abstracts of papers presented at the fourth annual meeting of the Canadian Phytopathological Society, Macdonald College, June 25–27, 1934, and published elsewhere.

11 : 35-40. 1934) as being due to magnesium deficiency, for which reason the above title has been tentatively given. Characteristic symptoms are confined to the foliar parts of the plant. In the incipient stages affected plants present a chlorotic appearance. In advanced stages the leaves develop an interveinal necrosis which may expand in size, ultimately involving the entire leaf blade. Leaves so affected, particularly the lower ones, usually drop off the plant. Affected plants usually die prematurely resulting in a material reduction in the yield of tubers. Analyses of soils from fields showing the disorder revealed that there is a marked deficiency in magnesium in these soils. In field trials the disorder was corrected and the yield of tubers increased by supplementing the ordinary fertilizer (4-6-10) with dolomitic lime, keiserite, magnesium sulphate and magnesium carbonate. All the forms of magnesium used in these trials were found to be equally effective when supplying the equivalent of 20 pounds of magnesium oxide per acre.

THE INFLUENCE OF ROOTLET KILLING ON THE GROWTH RESPONSE OF APPLE TREES GROWN IN LIQUID CULTURE. J. C. Roger, Dominion Laboratory of Plant Pathology, Summerland, B.C.

Field observations over a period of years have indicated that rootlet killing is commonly associated with the occurrence of such physiological diseases as drought spot and corky core of apple, gumming of prune, drought spot of apricot and cherry, etc. Laboratory experiments in 1933 on young apple trees grown in liquid culture, which were exposed periodically to varying degrees of rootlet killing, gave the following results. In spite of severe root killing, top growth took place continuously, if not normally or at a common rate, on all trees throughout the experiment. The rate of growth appeared to be influenced by conditions other than rootlet killing, as each change in growth rate took place at a similar time in both treated and untreated trees. Leaf scorch and die back, however, appeared to be related to root injury, as distinct symptoms of these occurred only on the treated trees. Periodic rootlet killing of 100% of the absorbing tissue did not prevent continued growth, and it was evident that absorption took place through this dead tissue.

A similar experiment in 1934 substantiated in general the 1933 results, especially with respect to the ability of trees to absorb moisture for considerable periods of time through dead rootlet tissue.

ON THE MERIT OF TREATING POTATO TUBERS TO REDUCE DISEASE AND LOSS CAUSED BY *RHIZOCTONIA SOLANI* KÜHN. G. B. Sanford, Dominion Laboratory of Plant Pathology, University of Alberta, Edmonton, Alberta.

Data, statistically analyzed, from 11 uniform experiments indicate the effect of treating seed potatoes bearing sclerotia of *Rhizoctonia Solani* on reducing—*(a)* lesions on the stem 32 days after planting, and *(b)* the yield at harvest. The types of soil used included those typical of Eastern Canada, and those typical of the prairie, wooded and organic black soils of Alberta. The sets were treated with effective mercuric chloride solution plus 10% by volume of hydrochloric acid. The disease was significantly transmitted to the stem (32 days after planting) from viable sclerotia on the sets in 8 of the 11 experiments. Significant results from treatment were not obtained in a single case where data were based on the total yield or on the yield of marketable tubers at harvest. As the study was repeated in 1934 complete results will appear later.

STUDIES ON THE OVERWINTERING OF CERTAIN FUNGI PARASITIC AND SAPROPHYTIC ON FRUIT TREES. L. W. Koch, Dominion Laboratory of Plant Pathology, St. Catharines, Ontario.

Dibotryon morbosum (Sch.) T. and S. has been isolated on numerous occasions during the winter from definite chlamydospores on buds and bark of *Prunus domestica*. Pure cultures of *D. morbosum* produced chlamydospores only when grown in close proximity to certain other organisms, or when certain chemicals were introduced into

the Petri dishes. Chlamydospore formation was also produced on twigs of *P. domestica* when conidia of *D. morbosum* germinated in intimate association with a strain of bacteria originally isolated from the same host. *Cladosporium carpophilum* was isolated in several instances from chlamydospores on the bark of *Prunus persica*. This organism also produced chlamydospores both on culture media and on peach twigs. A histological study revealed the presence of two types of twig lesions. *Taphrina deformans* was isolated during the winter from the surface of buds on *P. persica*. Proof is submitted that spores of *T. deformans* can remain viable throughout the winter on twigs of the above-mentioned host. Other fungi, presumably saprophytes, representing the genera *Coniothyrium*, *Cladosporium*, *Hormodendrum*, *Fumago*, and a fungus impossible to identify because it produced chlamydospores only, all developed from chlamydospores occurring on various hosts. The evidence obtained indicates the probability that many more fungi overwinter as chlamydospores than have been reported to do so. Due to their unsatisfactory mycological status the importance of chlamydospores has hitherto been incompletely appreciated. The results of these investigations emphasize the importance of the application of a dormant spray on fruit trees.

THE ANALYSIS OF A COMPLEX MOSAIC OF PRESIDENT POTATO. D. F. Putnam, Department of Botany, University of Toronto, Toronto, Ontario.

The potato variety President, which has for a number of years been grown in Nova Scotia under the name of Never Rot, is often affected by an obscure mosaic disease which differs from all of the standard named potato mosaics. The complex has been analysed and found to be an association of three viruses, two of which are apparently the same as the vein banding and mottle viruses found in the rugose mosaic complex. The third, which produces the typical yellow mottle associated with the disease, has not been reported before The ring spot virus was not found associated with the complex.

The yellow mottle virus apparently belongs to the X-group. It is not transmitted by the aphid *Myzus persicae*, but is sap transmissible and filterable. It is fairly resistant to ageing and to the action of chemicals, and has a thermal death point of approximately 72° C.

ANNUAL MEETING OF THE CANADIAN PHYTOPATHOLOGICAL SOCIETY

The fourth annual meeting of the Canadian Phytopathological Society was held at Macdonald College, June 26 and 27, 1934. Dr. D. L. Bailey, President of the Society was in the chair during the sessions devoted to the reading of papers or the transaction of the business of the Society. The papers that were read before the Society and that are now appearing in Scientific Agriculture were edited by Dr. J. H. Craigie, of the Editorial Committee. The following Officers were elected for the year 1934-35:

President—Dr. J. H. Craigie, Dominion Rust Research Laboratory, Winnipeg, Man.

Vice-President—Dr. H. R. McLarty, Dominion Laboratory of Plant Pathology, Summerland, B.C.

Secretary-Treasurer—Mr. I. L. Conners, Central Experimental Farm, Ottawa, Ontario. (Elected in 1933).

Councillor—Prof. J. G. Coulson, Macdonald College, Que.

Councillor—Dr. D. L. Bailey, University of Toronto, Toronto, Ontario. (Ex-officio).

BOOK REVIEW

HANDBUCH DER PFLANZENKRANKEITEN (Text book of plant diseases) founded by Paul Sorauer; in six volumes; edited by O. Appel. Sixth revised edition. First volume: non-parasitic and virus diseases. First Part, 123 text illustrations; 602 pages; bound 46 Reichsmark. Second Part, 147 illustrations; 561 pages; bound 44 Reichsmark. 1934. Published by Paul Parey—Berlin, Germany.

When some 54 years ago Sorauer issued the first edition of the now famous handbook, it was a most modest affair. Each new edition grew in size and today we have before us the first volume of the sixth edition in two formidable parts issued by Geheimrat Appel and a series of collaborators, well known in the world of plant pathological science. Each new edition of this well known text book marks something of an epoch, reflecting the vast progress which has been made throughout the world in plant pathology and the control of plant diseases.

The first volume of the sixth edition is of particular interest inasmuch as it has been completely and fundamentally rewritten. Indeed almost every chapter has been prepared by a specialist, which modus in view of the continuous advance in our knowledge of this branch of science, is to be welcomed. It would have been too much of an undertaking to endeavour to do justice to the subject single handed. Dr. Appel, the worthy successor to Sorauer in editing this edition is to be congratulated on the choice of his co-workers and experts.

Volume one of the sixth edition—some 1163 pages print, with 270 illustrations, most of which are refreshingly new and original—is divided into two handy separate parts, devoted to non-parasitic and virus diseases. The text is divided into eleven sections.

By way of making our readers familiar with the scope, it is instructive to glance through the table of contents and to have impressed upon one the extraordinary comprehensiveness of the material provided. Indeed once more is the reader reminded that plant pathology is no longer a phase of mycology nor a science merely devoted to researches on fungus parasites. Sorauer, years ago, emphasized the effect of environment and of predisposition of plants to parasitic fungi, and has provided us with a lasting discourse on non parasitic phenomena, which result definitely in ill health of plants, without any parasitic agent being involved. Thus today plant pathology, more so than ever, is a science devoted to research into the cause and prevention of ill health in plants, and requires the attention of the carefully trained specialist, thoroughly familiar with related sciences in every respect. The scope covered by this science nowadays is reflected by the various sections which are divided into a general and a special part. The first section of the general part has been prepared by Professor K. Braun who reviews the history of plant diseases and noxious insects up to the year 1880. Professor Morstatt follows with section two: General plant diseases with two subsections, I, the nature of diseases, and II, Ecology of disease. The introduction of his two groups makes interesting reading, dealing with the more recent development of plant pathology—pointing out that, after all, the broader conception of the science is but 50 (!) years old, Julius Kühn being the first to publish a textbook on the diseases of plants in 1858. Great credit is given to the development of this study in the U.S.A. where plant pathology no doubt has progressed by leaps and bounds. Morstatt might have taken more cognizance of the great organization of a plant pathological service in the Dominion, but, no doubt, since most of our earlier contributions to this science appeared in foreign journals, the identity was not disclosed—a defect which it is hoped is now offset by two excellent periodicals which will help to identify Canadian workers in future. In passing, it may also be said that Canadian plant disease legislation preceded that of the U.S.A.

The special part by Dr. Merkenschlager commences with a discussion of plant nutrition in its bearing on disease, or, rather, disorders in plants, since it is exclusively devoted to non parasitic causes. He discusses in detail biochemical symptoms such as the pathology of carbon hydrate, of albumin, gaseous metabolisms, etc. The pathology of mineral metabolism: calcium, potash, magnesium, phosphoric acid, nitrogen, etc., is dealt with in detail, followed by sections on excessive nutrition and special non-parasitic phytopathology.

Hiltner then takes up questions of the relation of climate and meteorological factors as causes of disorders, dealing with excess of light, light deficiency, temperature conditions, circulation and lack of water and similar factors.

Wartenberg discusses cold and heat as the cause of death in plants and of injuries to plant life, such as the death of the plant cell through low temperatures, the mechanical effect of frost or heat. The material is carefully selected and conveys to the reader a splendid idea of the significance of these factors as causes of ill health in plants.

K. O. Müller reviews disorders due to internal factors, disturbances in the embryonal period, during growth, or functions generally. Anything of interest during the period of reproduction also receives attention of this author.

Dr. Pfeil discusses unsuitable or unfavourable soil conditions as causes of disorders, physical as well as chemical.

Schlumberger leads a rather comprehensive discussion on wounds due to physical causes, the reaction of plants to wounds generally and with regeneration and correlation following wounds, cell-tissue regeneration, adventition buds, loss and replacement of roots, etc.

The seventh subsection is by Professor Tiegs and is devoted to fume injuries—a chapter always of interest to Canada with its many smelters and problems arising therefrom. This chapter is certainly most comprehensive in describing injuries due to a number of gaseous substances likely to be encountered.

He follows this section with a discussion of the effects on vegetation of waste waters mainly resulting from various industries.

Finally Dr. Köhler contributes a formidable section on virus diseases, some 182 pages in length. In view of the ever increasing importance of virus diseases in crops all over the world, this section is specially valuable. There is the general part, discussing etiology, the pathological morphology, anatomy and physiology. The action of the virus within the host, its transmission, the disease in its relation to external factors, questions of resistance, the virus in vitro—classification and control measures. This chapter is followed by the special part dealing with the viruses of the Solanaceae with fair detail. It is followed by a discussion of virus diseases affecting a host of non-solanaceous plants of which there is an alarming number in almost every climate of the universe. A 41-page index completes the two formidable volumes. Sorauer's Handbuch does not require special commendations and it is generally realized that no library is complete without it. It serves a most useful purpose as a work of reference and has become almost indispensable as such. Dr. Appel, the veteran of German plant pathologists, is to be congratulated in having accomplished a great and difficult task so satisfactorily.

H. T. Güssow.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

Wholesale prices in Canada registered a slight advance in January, the index rising from 71 2 in December to 71 5. The rise was quite general, each of the sub-indexes being higher than in the previous month with the exception of fibres, textiles, and textile products, which was unchanged. None of the commodity indexes showed a sharp advance, however, though that of animals and their products was most substantial. The index for January, 1935, was nearly a point above that for January, 1934.

Retail Prices—The index number of retail prices showed little change as compared with that for December. Food prices were lower, the index dropping from 69.3 to 68 8. The indexes for fuel and sundries were slightly higher but these advances did not offset the reduction in prices of food.

Physical Volume of Business.—The physical volume of business in December, 1934, showed a decline of a little over four points. Industrial production dropped from 97.0 to 91.0. Mineral production fell from 137 5 to 121 8. Exports of copper were greatly reduced as compared with those in November, in which month, however, they were exceptionally high. The shipments of gold were lower and coal production was slightly below that of the previous month. It should be pointed out that the indexes of physical volume of business, industrial production, and mineral production were all well above those in December, 1933.

In the manufacturing group the index declined from 96 0 in November to 91 8 in December. Manufacture of sugar and salmon exports were lower. Production of flour and oatmeal was not reported. Tobacco releases, boot and shoe production, and textile output were also lower. On the other hand, the index of iron and steel rose from 36 6 to 46 7 and automobile production showed an early advance, though the index was substantially below that for December, 1933. Imports of crude petroleum were lower than in the previous month. The construction index declined from 43 1 to 31 2. Trade employment was substantially better and car loadings were slightly lower than in November. Exports were a little higher and imports somewhat lower.

The movement of grains was very slow. In fact, the rate at which wheat has moved into export markets has been disappointing, and prospects now are that the carryover at the end of the crop year will be larger than anticipated. Live stock marketings were slightly off in December, the index dropping to 67 3, a decline of five and one-half points. Hog marketings were decidedly lower. Cattle shipments were also below those in November, but sheep and calves moved in larger volume. Cold storage holdings were slightly above the level of those at November first.

The December live stock and poultry survey has just been released by the Agricultural Branch of the Dominion Bureau of Statistics The number of cattle and calves on farms at December, 1934, was 8,484,000, a decrease of 5.2 per cent compared with June 1, 1934, but a somewhat larger number than were on farms at December 1, 1933. The reduction in numbers since June, 1934, has taken place in the Maritime Provinces, Quebec, Ontario, and Manitoba, the decrease in the latter three provinces being relatively smaller than in the Maritimes. In Saskatchewan, Alberta and British Columbia cattle numbers are definitely increasing. Prospects are that the number of cows to be bred during the period of December, 1934, to May, 1935 will be 5.7 per cent lower than in the same period of 1933-34.

The number of milch cows shows an increase of 5.1 per cent during the twelve months ending December 1, 1934. There has been an increase in all provinces except Prince Edward Island and Ontario. Cows for beef are increasing less rapidly than

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62 6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79 0	66 0				
1915	70.4	77.7	76.9	79 2	67 3				
1916	84 3	89 7	88.4	92.3	72 5				
1917	114.3	130 0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65 5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75 0	69.9	52 6	94.2
1921	110.0	102 8	100 3	108 5	109.2	66 5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100 0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95 1	100.0	85 5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98 0	84 6	82 4	102 5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89 7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100 0	100 0	100.0	100 0	100.0
1927	97.7	102.1	99.9	105.7	98 4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114 3	98.9	117 3	117.8	146.7	112.8
1929	95.6	100 8	93.8	112.5	99.9	125 5	127.4	101.1	109.6
1930	86.6	82.3	70 0	102 9	99.2	109 5	108 0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89 6	93.5	90 4	99.0	125.7
1932	66 7	48.4	41 1	60.7	81.4	78.7	74 0	114 3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1934	71.6	59.0	53.9	67.6	78 9	94.2	93 6	88 5	114.2
1934									
Jan.	70.6	55.3	47.9	67 8	78.2	86.8	84 5	48.2	108.1
Feb.	72.1	58 0	49 3	72 5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79 9	93.1	92.0	63.8	97.0
Apr	71.1	55.4	48.7	66 6	79 4	92 6	91 4	56 9	94.5
May	71.1	56.9	51.1	66 5	78.5	99.6	99.4	130 6	102.6
June	72.1	59.3	55.5	65.6	78.2	95 8	95 2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95 6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172 8	114.7
Sept.	72.0	61.3	58.9	65.3	79 0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55 3	70.4	79.3	95.8	95.3	61.2	128.8
Nov.	71.2	61 2	55 7	70.4	79.4	96.5	97.0	51 2	130.4
Dec.	71 2	61.6	56.0	70.9	79.0	92 4	91.0	36 0	135.7
1935									
Jan.	71.5	61.4	55.7	71.0	78 9				

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1932, p. 15.

2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1932, p. 32, and Monthly Mimeographs 1933 and 1934.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries, See Prices and price Indexes 1913-1928, pp. 181-185, 290-293. 1926=100.

Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeographs 1933-1934.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics November, 1932.

those kept chiefly for milking. There has been a reduction of 45,000 head of calves compared with December 1, 1933, and 300,700 since June 1, 1934. Moreover, there has been a reduction of 56,000 head of steers, two years and over, since the survey taken at December 1, 1933. The trend of cattle numbers is indicated by the reduction in the number of calves. Shortage of feed in some areas is, however, a contributing factor.

Numbers of hogs have decreased slightly since the first of June, 1934, but there were 61,000 more hogs on farms in December, 1934, than at the same date in 1933. The increase has been accounted for in the Maritime Provinces, Quebec and Manitoba, but elsewhere hog numbers are lower. Farrowings were slightly higher in the period June to December, 1934, and there is a slight tendency to increase farrowings during the next six months. There will likely be an increase during the first half of the year in marketings but in the fall of 1935 it is likely marketings will show no appreciable increase.

The number of sheep and lambs on farms was substantially the same as in the previous year. There have been decreases in the Maritime Provinces and in Ontario, Manitoba, and British Columbia, whereas Quebec, Saskatchewan, and Alberta showed increases, particularly in the two western provinces. The number of ewes to lamb will be slightly less than indicated by the survey taken in December, 1933.

The number of hens and chickens was slightly lower at the end of 1934.

The survey indicates a reduction in cattle population, notably in numbers of calves, an increase of about 5 per cent in the number of milch cows, a small increase in the number of hogs; substantially the same number of sheep and lambs, and a small reduction in the number of hens and chickens on farms.

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE, OTTAWA, PRINCIPALEMENT D'APRÈS LES DONNÉES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

En janvier les prix du gros au Canada ont enregistré une légère hausse, l'indice passant de 71.2 en décembre à 71.5. Cette hausse a été très générale; à l'exception des fibres, des textiles et des produits textiles qui n'ont pas changé chacun des sous-indices était plus élevé qu'au cours du mois précédent. Elle était légère pour les indices relatifs aux marchandises mais prononcée sur les animaux et leurs produits. L'indice de janvier 1935 était de près d'un point supérieur à celui de janvier 1934.

Prix de détail.—Le chiffre indice des prix de détail n'accusait que peu de changement sur celui de décembre. Les prix des denrées alimentaires étaient plus bas, l'indice tombant de 69.3 à 68.8. Les indices pour le combustible et les produits divers étaient un peu plus élevés mais ces hausses n'ont pas été suffisantes pour couvrir la diminution qui s'est produite dans les prix des denrées alimentaires.

Volume physique des affaires.—En décembre 1934, le volume physique des affaires révélait une diminution d'un peu plus de quatre points. La production industrielle est tombée de 97 0 à 91.0, la production minérale de 137 5 à 121.8. Les exportations de cuivre étaient grandement réduites par comparaison à celles de novembre, mais elles étaient exceptionnellement élevées dans ce mois-là. Les expéditions d'or avaient diminué et la production de charbon était un peu inférieure à celle du mois précédent. Il est à noter que les indices du volume physique des affaires, de la production industrielle et de la production minérale étaient tous bien supérieurs à ceux de décembre 1933.

Dans le groupe manufacturier, l'indice qui était de 96 0 en novembre est tombé à 91 8 en décembre. La fabrication du sucre et les exportations de saumon ont diminué. Il n'a pas été fait rapport de la production de farine et de farine d'avoine. Les ventes de tabac, la production de chaussures, la production textile avaient également diminué. Par contre, l'indice du fer et de l'acier s'est élevé de 36 6 à 46.7, la production des automobiles a enregistré une augmentation quoique l'indice ait été bien inférieur à celui de décembre 1933. Les importations de pétrole brut étaient inférieures à celles du mois précédent. L'indice du bâtiment a baissé de 43.1 à 31.2. Le nombre d'employés dans le commerce avait bien augmenté, mais les chargements de wagons étaient un peu inférieurs à ceux de novembre. Les exportations étaient un peu plus fortes et les importations un peu moins élevées.

Le mouvement des grains a été très lent. En fait, le peu de rapidité avec lequel le blé a été transporté sur les marchés d'exportation a causé un désappointement et il est maintenant à prévoir que le reliquat à la fin de l'année de récolte sera plus considérable qu'on ne le prévoyait. Les ventes de bestiaux ont légèrement diminué en décembre, l'indice tombant à 67.3, soit une baisse de cinq points et demi. Les ventes de porcs ont aussi beaucoup diminué. Les expéditions de bovins étaient également inférieures à celles de novembre, tandis que celles de moutons et de veaux étaient plus considérables. La quantité de produits entreposés au froid était un peu plus forte qu'au 1er novembre.

Les résultats du recensement de décembre sur les bestiaux et les volailles viennent d'être publiés par la Division de l'agriculture du Bureau fédéral de la statistique. En décembre 1934, le nombre de bovins adultes et de veaux sur les fermes était de 8,484,000, soit une diminution de 5.2 pour cent par comparaison au chiffre du 1er juin 1934, mais une légère augmentation sur le chiffre du 1er décembre 1933 La diminution qui s'est produite depuis juin 1934 a eu lieu dans les provincesMaritimes le Québec, l'Ontario et le Manitoba; elle était relativement plus faible dans ces trois dernières provinces que dans les provinces Maritimes. La population bovine est en augmentation dans la Saskatchewan, l'Alberta et la Colombie-Britannique. On

prévoit que le nombre de vaches à faire saillir pendant la période allant de décembre 1934, à mai 1935 sera de 5.7 pour cent moins élevé qu'au cours de la même période de 1933-34.

Le nombre de vaches laitières a augmenté de 5 1 pour cent pendant les douze mois finissant au 1er décembre 1934. Il y a eu augmentation dans toutes les provinces, sauf dans l'Ile du Prince-Edouard et dans l'Ontario. Le nombre de vaches destinées à la boucherie augmente moins rapidement que celles que l'on garde principalement pour la traite. Il y a eu une réduction de 45,000 veaux depuis le 1er décembre 1933 et de 300,700 depuis le 1er juin 1934. En outre, il y a eu une diminution de 56,000 bœufs de deux ans et plus depuis le recensement du 1er décembre 1933. La courbe du nombre des bovins est indiquée par la réduction dans le non.bre des veaux, mais le manque d'aliments dans certaines régions est pour quelque chose dans cette situation.

Le nombre de porcs a un peu diminué depuis le 1er juin 1934, mais il y avait, en décembre 1934, 61,000 porcs de plus sur les fermes qu'à la même date en 1933. Cette augmentation a été notée dans les provinces Maritimes, le Québec et le Manitoba; partout ailleurs, le nombre de porcs a diminué. Le nombre de mises-bas a été un peu plus élevé pendant la période qui s'est écoulée entre juin et décembre 1934, et il a une légère tendance à augmenter le nombre des mises-bas pendant les prochains six mois. Il y aura sans doute une augmentation dans les ventes pendant la première moitié de l'année mais il est peu probable que le chiffre des ventes accuse une augmentation sensible dans l'automne de 1935.

Le nombre de moutons et d'agneaux sur les fermes était à peu près le même que l'année précédente. On a enregistré des diminutions dans les Provinces Maritimes ainsi que dans l'Ontario, le Manitoba, et la Colombie-Britannique, tandis que le Québec, la Saskatchewan, et l'Alberta enregistraient une augmentation, spécialement dans les deux provinces de l'Ouest. Le nombre de brebis qui vont mettre bas est un peu moins élevé que l'indiquait le recensement qui a été effectué en décembre 1933.

Le nombre de poules et de poulets était un peu plus faible à la fin de 1934.

Le recensement indique une diminution dans la population des bovins, surtout dans le nombre de veaux, une augmentation d'environ 5 pour cent dans le nombre des vaches laitières, une faible augmentation dans le nombre des porcs, à peu près le même nombre de moutons et d'agneaux, et une faible réduction dans le nombre de poules et de poulets sur les fermes.

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THE ADDITION OF PROTEIN AND CALCIUM TO A RATION OF SMALL GRAINS FOR GROWING PIGS

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It is well known that swine, of all farm animals, are the most likely to suffer from inadequate rations. This is due to two principal causes. In the first place they are fed largely on grain and get relatively little roughage, especially when they are fed under conditions of close housing and in the second place they grow more rapidly than other farm animals in relation to their weight at birth with the result that their requirements for essential dietary constituents are more exacting.

Chemical analyses only confirm what practical experience and experimental results have fully demonstrated—that the essential food constituents (aside from vitamins) most apt to be deficient in the ordinary farm grown grains, from the standpoint of the growing, fattening pig, are protein and the element calcium. According to Morrison's Feeding Standards (*1*) a pig of 75 pounds live weight would have to consume roughly 4½ pounds of oats per day to obtain the required amount of digestible crude protein, while to secure .02 lbs. per day of lime (CaO) as recommended by Orr (*2*) it would have to consume 14 lbs. of the same grain. Since the other two grains commonly fed in Western Canada—barley and wheat—are quite similar in composition, it is obvious that young growing pigs cannot satisfy their demands for protein and calcium from grains alone.

Since protein and mineral supplements form the most expensive portion of a growing and fattening ration it therefore becomes important to make a careful study of the requirements of the pig for these constituents so that only the optimum amounts may be provided in the diet. Moreover, since the addition of protein to a basal ration of farm grains increases the rate of growth, thereby increasing the demand for material for skeletal development, it might be expected that the mineral requirements would vary somewhat with the level of protein intake. A series of experiments designed to study the effect of adding protein and calcium to a cereal ration for pigs was conducted at the University of Alberta during the summer of 1932, winter of 1932-33, summer of 1933, and winter of 1933-34.

PLAN OF THE EXPERIMENTS

These experiments were planned so that one group of pigs was carried on a non-supplemented cereal ration. Two series of groups were included, one with ground limestone added to the cereal ration as a source of calcium, and one without the addition of this mineral supplement. In both series the protein level of the ration was increased by stages by the addition of a supplement consisting of a meat meal and linseed oil meal mixture.

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This arrangement of experimental groups made provision for a study of the effect of varying the level of protein in the ration under conditions of both low and high calcium intake and constituted a basis for determining the comparative deficiencies of protein and calcium in a ration made up of the small grains.

The pigs were confined to the piggery during the course of the experiments on a concrete floor provided with a wooden sleeping platform. The piggery was reasonably well lighted through ordinary glass windows. Straw was used for bedding.

In the first experiment the ration was hand fed in slop form and in the last three experiments dry feeding from self-feeders was practised.

From the point of view of arrangement of groups the following plan was adopted:

Group I. Basal ration.
Group II. Basal ration + 3 3% protein supplement.
Group III. Basal ration + 6 7% protein supplement.
Group IV. Basal ration + 10 0% protein supplement.
Group V. Basal ration + Gr. limestone.
Group VI. Basal ration + Gr. limestone + 3.3% protein supplement.
Group VII. Basal ration + Gr. limestone + 6.7% protein supplement.
Group VIII. Basal ration + Gr. limestone + 10 0% protein supplement.

Grain

The grain ration used in these experiments consisted of ground oats 50%, ground barley 25% and ground wheat 25%.

Protein Supplement

The protein supplement consisted of a packing house meat meal known as "Super 70" meat scrap together with linseed oil meal. The meat meal made up 75% of the mixture with linseed oil meal 25%. This particular mixture was used with a view to securing a mixture carrying a relatively low ash content.

Ground Limestone

In the groups receiving additional calcium this was added as finely pulverized ground limestone in the amount of 2 pounds per 100 pounds of grain and supplement mixture. A slight deviation from this plan was made in the fourth experiment when the amount of ground limestone was reduced to 1 lb. in 100 lbs. during the latter stages of the trial.

Salt

In all groups 1 pound of salt was added to 100 pounds of the grain and supplemental mixture.

Cod Liver Oil

In the first experiment each pig was fed 10 ccs. of crude cod liver oil daily. In the last three experiments of the series the cod liver oil was fed at the rate of 1 pound to each 100 pounds of the ration.

Chemical Analysis of the Ration

In connection with all experiments composite samples of the various feed sused were collected during the progress of the trials and the percentage of crude protein, calcium and phosphorus was determined. The results

of these analyses based on an average of the four experiments is shown in Table 1.

TABLE 1.—CHEMICAL ANALYSIS OF THE RATION

	Oats	Barley	Wheat	Meat meal	Linseed oil meal
Crude protein, %	12 59	12 70	13 19	70 47	39 44
Ash, %	2 87	2 18	1 63	7 07	4 78
CaO of ash, %	1 81	1 45	2 05	26 10	8 77
P_2O_5 of ash, %	25 03	33 28	48 84	34 02	30 74

The figures secured from these analyses were used as a basis for calculating the daily intake of the various food factors under consideration. The low ash content of the cereals is worth noting and in addition the high proportion of phosphorus to calcium is of special significance.

RESULTS OF THE EXPERIMENTS

Space will not permit the presentation of data nor a discussion of the results of individual experiments. Since the same general plan was followed in all experiments it has been thought proper to present tables and a discussion based on average results of the four trials. The only major deviation from the plan already outlined occured in Experiment IV when Lot VIII (basal ration + ground limestone + 10% supplement) was eliminated and a group, designated as Group A, where the non-supplemented cereal ration fed without the addition of cod liver oil was included.

The results of the experiments will be interpreted on the basis of growth rates, feed utilization and blood composition, in terms of calcium and inorganic phosphorus of the serum. Blood samples were taken from the tail and analysed for calcium according to the Clark-Collip Modification of the Kramer-Tisdall method and for inorganic phosphorus by the Fiske and Subbarrow method.

Daily Intake of Food

In order to obtain a picture of the daily intake of protein, calcium and phosphorus and to study the effect of modifying the percentage of protein supplement in the ration as well as adding ground limestone on the intake of these constituents, Table 2 is presented. The figure for Digestible Crude Protein was obtained by applying the digestibility co-efficients of Henry and Morrison to the figures obtained by chemical analyses of the individual feeds. Weights are expressed in grams rather than in pounds in order to enable the figures for calcium and phosphorus to be more easily related to similar studies.

It will be noted that the average daily intake per 100 pounds live weight of digestible crude protein varied from 174 grams in Lot I to 256 grams in Lot VIII. According to Morrison's Feeding Standards (*1*) pigs of 100 pounds live weight should receive in the region of 235 grams (0.52 lb.) of digestible crude protein daily. Using Wood's Feeding Standards as a basis Davidson (*3*) places the digestible crude protein requirement of 100-pound pigs at a similar level of 0.51 lb. per day. These figures, then, would indicate that the grains used were definitely deficient in protein since it required the addition of 10% of the supplement used to raise the level of protein to meet these recommendations.

The calcium intake in the different lots varied rather widely, from 0.52 grams daily in Lot I to 14.84 in Lot VIII or from 0.030% to .865% of the ration. Taking as a basis the recent work of either Spildo (*4*) who considers that about 5–7 grams (0.35% of the ration) of calcium should be supplied per animal per day for growth alone, or of Bethke, Edington and Kick (*5*) who found that calcium should constitute about 0.6–1.2% of the ration, it is quite evident that a basal ration of farm grains as fed to Lot I is very deficient in the element calcium. Even when the basal ration was supplemented with 10% (Lot IV) of the protein supplement, the level of calcium being fed remained well below either of these recommendations. The addition of 2 pounds of ground limestone to each 100 pounds of the grain mixture provided approximately twice as much calcium as is recommended by Spildo and brought the figure into the region recommended by Bethke, Edington and Kick.

TABLE 2.—DAILY INTAKE OF D.C P., CALCIUM AND PHOSPHORUS PER 100 LBS. LIVE WEIGHT

Lot No.	Daily food intake gms	Total D.C.P. gms.	Per cent of ration D C P.	Total Ca gms.	Per cent of ration Ca	Total P gms.	Per cent of ration P	Ratio Ca : P
I	1720	174	10 2	0 52	030	5 56	323	.092 : 1
II	1706	200	11 8	1 11	065	5 87	344	190 : 1
III	1692	226	13 4	1 70	101	6 19	365	278 . 1
IV	1695	254	15 0	2 29	135	6 56	385	352 : 1
V	1818	180	10 0	13 07	.722	5 76	317	2 30 : 1
VI	1802	207	11 6	13 46	.746	6 07	338	2 22 : 1
VII	1738	227	13.2	13 53	.778	6 22	358	2 18 : 1
VIII	1714	256	15 0	14 84	865	6 38	372	2 33 : 1

The phosphorus requirement also is placed by Spildo (*4*) at about 0.35% of the ration, while the Ohio workers (*5*) place the figure at 0.6% of the ration. If the Ohio figures are to be taken as applicable to the conditions of this experiment, it might appear that the phosphorus as well as the calcium content of the ration was low. On the basis of Spildo's figures, however, the phosphorus content of the ration was just sufficient.

It must be noted here that according to the recommendations of the above workers, the Ca : P ratio was somewhat too wide in all lots which received ground limestone.

Rate of Growth

The pigs confined to the basal ration in these experiments made very unsatisfactory gains as compared with those whose rations were supplemented by the protein mixture or by ground limestone or a combination of both. The rate of growth of these pigs indicates quite definitely that a ration composed of cereals alone is unsatisfactory for pigs of the ages and weights used in these trials. The addition of the protein mixture in percentages of 3.3 to 6.7% and 10% resulted in progressive improvement in rate of growth, the increase in the rate of gains over the basal group being on the order of 35%, 57% and 75% as the protein allowance was increased.

That a calcium deficiency also was in part responsible for the indifferent growth rate of the pigs receiving the basal ration only, is indicated

TABLE 3.—AVERAGE DAILY GAINS

Lot No.		Average initial weight lbs.	Average final weight lbs.	Average daily gain lbs.
I	Basal	50 7	139 1	0.69
II	Basal + 3 3% P S	51 0	170 8	0.93
III	Basal + 6 7% P.S.	50 9	184 8	1 08
IV	Basal + 10 0% P.S.	50 3	199.6	1 21
V	Basal + Gr. L.	50 3	166 9	0.92
VI	Basal + Gr L. + 3 3% P.S.	50 8	196 1	1.20
VII	Basal + Gr. L. + 6 7% P.S	49 9	200 1	1.24
VIII	Basal + Gr. L. + 10 0% P.S.	50 1	200 6	1 27

by the improvement effected by adding ground limestone. When ground limestone was added without any change in the protein fraction of the ration the rate of gain was increased from 69 pound to .92 pound daily. The addition of ground limestone to the groups receiving the 3.3% and 6 7 % protein allowances also resulted in a significant improvement in daily gains indicating that calcium deficiency was a growth limiting factor in Lots II and III. The point at which the addition of ground limestone appeared to fail to make a marked impression on the rate of gains was when the protein supplement mixture was added at the rate of 10%. This would suggest that the additional calcium supplied by the protein supplement when fed at the 10% level was almost sufficient to satisfy at least the minimum requirements of the pigs for this element. A reference to Table 2 shows that these pigs received a daily quota of 2.29 grams of calcium (0 135% of the ration) and 254 grams of digestible crude protein (15% of the ration) per 100 lbs. live weight. In contrast to this, the pigs receiving 10% of the protein supplement + ground limestone received 0 865% calcium and 15% digestible crude protein.

Since the pigs on a daily intake of 2.29 grams of calcium made as satisfactory growth as other pigs receiving much larger allowances it would appear that the optimum allowance for such pigs as were used in these trials cannot be greatly in excess of the above figures. It may at least be suggested that the amount of from 13 to 14 grams is considerably in excess of actual requirements. In this connection it may be pointed out that no cases of crippling occurred in the 10% protein-no limestone lot, an occurrence which indicates that the calcium intake was sufficient and the Ca/P ratio such that clinical symptoms of rickets or related conditions were prevented. However, since crippling occurred in the other groups in the "no limestone" series it is obvious that the daily intake of 2 29 grams was decidedly marginal.

From the standpoint of rate of gains it would seem that a daily allowance of digestible crude protein up to 250 grams, or at the rate of 15% of the ration is justified as compared with the use of more limited allowances. That the drawing of any definite conclusion in this regard is not justified, however, is indicated by the fact that when ground limestone was supplied and the complication of calcium deficiency was removed the use of the protein supplement at the lower levels gave almost as good results

as when fed at the rate of 10%. The introduction of additional calcium through the increasing ash content of the protein supplement when fed in increasing amounts introduces a conflicting situation which makes it inadvisable to be too dogmatic regarding the optimum protein allowance. Had an adequate protein supplement with an even lower ash content than the one used in this experiment been selected it might have been possible to make a more definite recommendation in this regard. It is obvious that the fluctuations in ash content of various protein supplements must be taken into account when their efficiency is being considered. The growth curves shown in Figure 1 will be of interest in connection with a comparison of the rate of growth in the various groups.

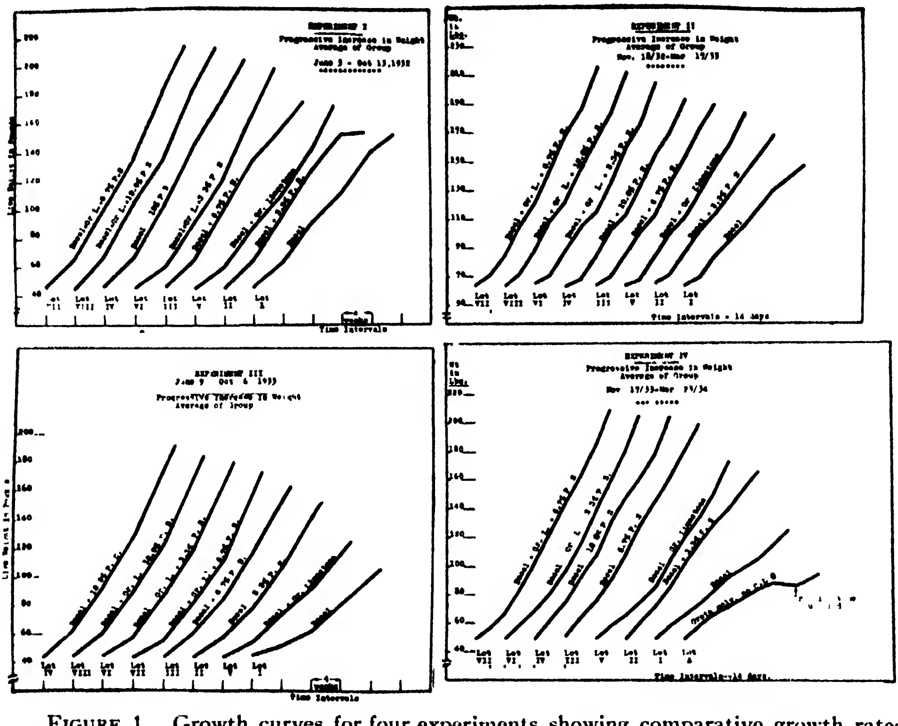

FIGURE 1. Growth curves for four experiments showing comparative growth rates for the various group of pigs.

Feed Requirement for Growth

Turning to a consideration of the various groups from the standpoint of efficiency of food utilization, it will be noted from Table 4, that the pigs receiving the grains non-supplemented made a poor showing as compared with the other groups on the experiment. The figure of 524.8 pounds of grain for 100 pounds increase in live weight suggests inefficient production in the basal group. The addition of the protein supplement in varying amounts, as was the case in respect to daily gains, resulted in progressive decreases in the amount of feed required per unit of increase in live weight. The saving in feed resulting from the addition of the protein mixture may best be expressed in terms of pounds of grain saved by each one pound of supplement fed. Reference to Table 4 will show that one pound of the

supplement replaced 6.3 pounds of grain when fed at the rate of 3.3%, 5.4 pounds when fed at the rate of 6 7% and 4.5 pounds when 10% was allowed. When fed without ground limestone the use of the supplement up to 10% would be justified when the cost of one pound would not exceed the value of 4 5 pounds of grain. Without regard to economy, it may be stated that under the conditions of the first four lots of the experiment, improvement was effected in feed utilization when the total digestible crude protein content of the ration was increased to 15% (Table 4).

When the mineral content of the ration was fortified by ground limestone a somewhat different situation developed. Under these conditions the improvement effected by the increase in the ash content when the protein supplement was fed at the higher levels was eliminated and a truer value for protein was secured. When Lot V is used as the check lot in the limestone series the grain saved by each pound of the protein mixture amounts to 5.5 lbs. in the 3 3% group, 4 5 lbs. in the 6.7% group and 3.7 lbs. in the 10% group, figures which are lower than when the limestone was not included. If economy of production is disregarded, it may be concluded that the use of the protein supplement up to a point where 15% of digestible crude protein was supplied was justified; but, since the saving of grain by the supplement diminished to a point where only 3.7 pounds of grain was replaced by each one pound of supplement when it was fed at the 10% level the practical value of feeding at that rate is open to question. Placing an arbitrary value of 0.5 cents per pound on the grains fed it would be necessary to secure the supplement at a cost of below $30.00 per ton before its use at the higher level would be justified.

TABLE 4. - FEED REQUIREMENT FOR GROWTH

Lot No.	Average daily feed consumed, lbs.	Pounds feed required per 100 lbs. gain			Pounds grain saved by 1 lb. of:	
		Grain	P.S.	Gr L	P.S.	Gr. L.
I Basal	3 64	524 8	—		—	—
II Basal + 3 3% P.S	4 16	433 0	14 6	—	6 3	—
III Basal + 6 7% P S.	4 41	378 2	27 3	—	5 4	—
IV Basal + 10 0% P.S.	4 69	350 1	38 9	—	4 5	—
V Basal + Gr. L.	4 35	463 3	-	8 6	—	7 2
VI Basal + Gr.L. + 3 3% P.S.	4 90	389 5	13 4	7 5	5 5	5 8
VII Basal + Gr L. + 6 7% P.S.	4 79	351 5	25 1	7 0	4 5	3 8
VIII Basal + Gr.L. + 10 0% P.S.	4 75	329 4	36 5	7 3	3 7	2.8

Attention must be drawn to the saving of grain by the use of ground limestone. The addition of ground limestone resulted in a marked improvement in efficiency of feed utilization, indicating that calcium as well as protein deficiency in the farm grown grains is definitely a limiting factor in securing satisfactory returns on grain consumed. Reference to Table 4 will suggest that in the main, one pound of ground limestone had a higher replacement value than one pound of the protein supplement. This, combined with the fact that there was no indication of crippling in the "no protein supplement-limestone" group, (V) justifies the statement that calcium deficiency constitutes a more serious limiting factor than

protein deficiency in the development of such pigs as were used in the series of experiments under review.

It will be noted that as the percentage of protein supplement in the ration was increased the grain replacement value of the ground limestone was diminished. Its replacement value was highest when the protein supplement was not fed or was fed at the lower levels.

Calcium and Inorganic Phosphorus of the Blood Serum

In two of the experiments conducted (I and IV) the level of blood calcium in the basal, 3.3% and 6.7% protein supplement groups fell below 10 mg. per 100 cc. of blood serum. The low level of blood calcium was accompanied by the development of stiffness or actual crippling in these lots. The severity of the condition increased as the level of blood calcium fell. Similar results were obtained by Sinclair (*6*). In Experiments II and III, although the level of blood calcium in the "no limestone" groups was lower than in the "limestone" groups, it did not fall below 10 mg. The few cases of stiffness which developed in these trials were of a mild character.

At the close of Experiment I, ground limestone was fed to the pigs of the first three lots (low-calcium) for a period of 39 days. This addition to the diet effected a marked improvement in these pigs as evidenced by

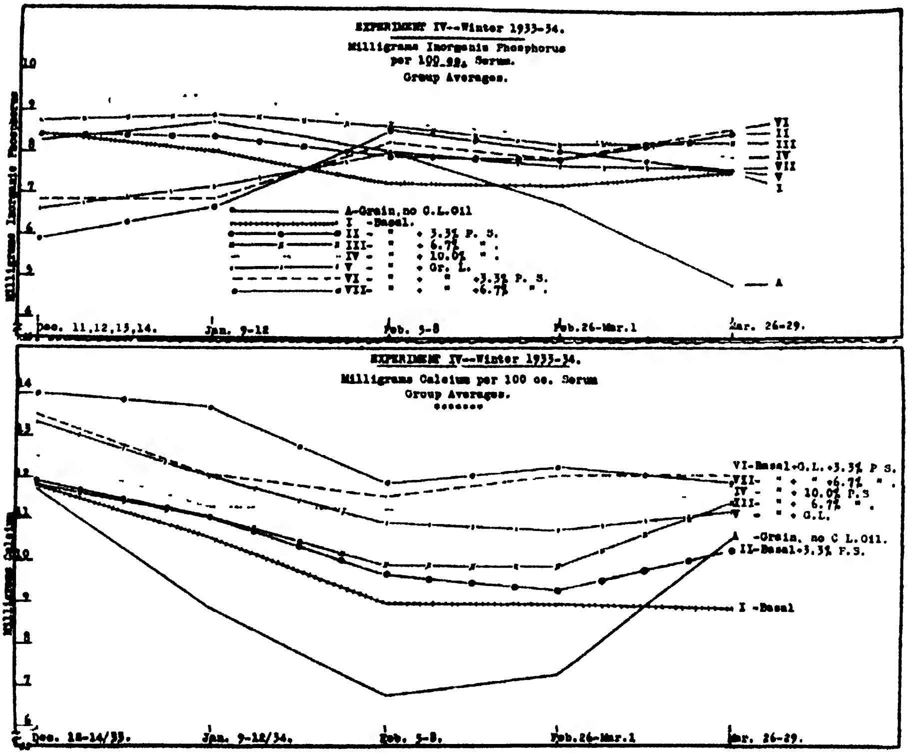

FIGURE 2. Chart showing inorganic phosphorus and calcium level of the blood serum at intervals during the progress of Experiment IV (winter 1933-34).

an increased rate of growth and a restoration of normal or nearly normal locomotary powers. A blood analysis on the 39th day showed that the blood calcium had risen to an average level of 12.8 mg. for the three lots. Similar results were obtained in Experiment IV, when ground limestone was added to the ration of the Group A pigs (See Figure 2). This group did not receive cod liver oil during the course of the trial, but even in its absence the addition of ground limestone restored the appetite of the pigs and altered their growth curve from a negative to a positive. After 25 days a blood analysis showed that the level of calcium had risen 3.3 mg. and stood at a level of 10.51 mg. per 100 cc. of blood serum. This rise in the level of calcium was accompanied by a marked improvement in locomotary ability. These results indicate that the calcium of ground limestone can be assimilated by pigs in either the presence or absence of cod liver oil, and that its assimilation was associated with a recovery from the crippled condition which existed in these low-calcium pigs.

In a discussion of the results of the inorganic phosphorus determinations, it may be stated that the results in Experiment II and perhaps in Experiment III suggest that in the low-limestone groups, a low level of blood calcium was accompanied by a high level of inorganic phosphorus. This is in agreement with the findings of Sinclair (*6*). On the other hand in Experiments I and IV this reciprocal relationship was not demonstrated to the same extent (See Figure 2), and a slightly subnormal inorganic phosphorus accompanied a low blood calcium. In this connection it is perhaps significant that the blood calcium in Experiments II and III, where the reciprocal relationship between calcium and phosphorus was demonstrated, stood at a level of 10 + mg. per 100 cc, while in Experiments I and IV the blood calcium fell to around 8 mg. This suggests that under the conditions of this trial a reciprocal relationship existed between blood calcium and phosphorus when the calcium was moderately low, but when the fall in calcium was very marked this reciprocal relationship was lost.

Phosphatase Determinations

Little has been done to investigate the significance of the phosphatase content of the blood of farm animals as associated with abnormal or unsatisfactory bone development. Phosphatase is the enzyme which hydrolyses phosphoric esters such as glycero-phosphate and hexose phosphate. According to Robison's (*7*) theory of ossification the presence of soluble organic calcium phosphates in the blood is assumed, and it is considered that the very active phosphatase present in the epiphyseal zone and periosteum plays an important part in bone formation by splitting off inorganic calcium phosphate at the sites of ossification. Kay (*8*) who is perhaps the outstanding authority on the subject of phosphatase makes this statement:

> "In addition to the two constituents of the blood which have been known for some years to be affected to a greater or less extent in bone diseases, namely the serum calcium and inorganic phosphate, we have now a third variable—the plasma phosphatase which suffers still greater changes."

Since it has been found (*9*) that deep seated distrubances of bone metabolism in man and various small experimental animals are accompanied by an unusually high concentration of phosphatase in the plasma it is of

Group A. Grain only, no cod liver oil.

Group I Basal Ration (Grain + cod liver oil).

Group V. Basal Ration + Ground Limestone.

Group VII. Basal Ration + Gr. L. + 6.7% P S.

Figure 3—Representative Groups of Pigs in Experiment IV (Winter, 1933–34)

interest to study the phosphatase level in pigs showing clinical symptoms of a lack of sufficient calcium for bone development.

In connection with Experiment IV, a cursory study was carried out on the amount of the enzyme phosphatase present in the blood of pigs exhibiting clinical signs of a deficiency of calcium for normal bone development. In making these determinations the method of Jenner and Kay (*10*) was followed except in one detail: viz. blood serum was used instead of blood plasma. The blood samples were drawn from the tail in the usual manner. The results obtained are presented in Table 5.

TABLE 5.—LEVEL OF BLOOD SERUM PHOSPHATASE

Date	Group No.	Pig No.	Phosphatase	Condition of pig
2/26/34	A	328	12 84	Active.
2/27/34	A	280	14 66	Badly crippled. Unable to walk.
2/28/34	A	336	9 42	Crippled, but able to walk.
3/ 1/34	A	311	8 04	Crippled, some difficulty in walking.
3/23/34	I	369	15 72	Rear legs bowed, all legs stiff.
3/23/34	I	304	8 82	Stiff in hind quarters.
			11 58	(Average for low-calcium pigs)
3/23/34	VII	368	5 40	Apparently normal and thrifty.
3/23/34	VII	372	4 02	Apparently normal and thrifty.
			4 71	(Average for high-calcium pigs)

It is realized that the volume of data presented is limited, but the results at least indicate that the level of phosphatase in the blood of the crippled, low-calcium pigs was definitely higher than in the apparently normal high-calcium pigs. This may be taken (*9*) as further evidence of a disturbance in the bone metabolism of the low-calcium pigs.

The Influence of Cod Liver Oil

In the first three experiments of the series under review cod liver oil was fed in all lots as a source of vitamins A and D. In connection with the fourth experiment it was thought well, as has already been mentioned, to include a group designated as Group A, in order to check the efficiency of the cod liver oil from the point of view of its growth promoting quality and the effect on calcium and phosphorus metabolism under conditions of a non-supplemented cereal diet.

The pigs in Group A (see Figure 3)after attaining a weight of 89.1 pounds at the end of twelve weeks on experiment became very unthrifty in appearance and their appetite was decidedly poor. At this stage these pigs were all crippled or stiff whereas this condition was not nearly as marked in Lot I, receiving a 1% allowance of cod liver oil. The average daily gain per pig for the entire period of the experiment (130 days) was 0.40 pound for Group A and 0.66 for Group I. Blood analyses during the months of December, January and February showed levels of 8.86, 6.75 and 7.21 milligrams of calcium per 100 ccs. of blood serum in Group A as

compared with levels of 10.52, 8.89 and 8.84 in Group 1, indicating that the cod liver oil was exerting an influence on the assimilation of the small amount of calcium present in the cereal ration.

CONCLUSIONS

The following conclusions may be drawn from the results of the experiments which have been reviewed in this paper:—

1. A basal ration of wheat, oats and barley supplying approximately 175 grams of digestible crude protein and 0.5 gram of calcium daily per 100 pounds live weight is inadequate for growing and fattening pigs of 50-200 lbs. live weight. Pigs fed such a ration grew slowly, became "stiff" or "crippled" and failed to make economical use of their feed.

2. The calcium of ground limestone can be assimilated by pigs. The addition of ground limestone to the basal ration led to the development of apparently normal bone and increased both the rate of growth and economy of feed utilization.

3. The beneficial effects of adding protein to the basal ration without supplying additional calcium were interferred with by the development of a condition of "stiffness" or "crippling" in the pigs.

4. The addition of ground limestone to such rations prevented the development of "stiffness," and promoted growth and more economical feed utilization.

5. Feeding a low-calcium diet led to a diminution in the amount of calcium in the blood serum. No consistent changes occurred in the level of inorganic phosphorus.

6. A low-level of calcium in the blood serum was found to be associated with the development of "stiffness" or "crippling."

7. Feeding ground limestone raised the level of calcium in the blood serum.

8. Indications were obtained that pigs exhibiting clinical symptoms of abnormal bone development due to a deficiency of calcium have a greater amount of phosphatase present in their blood than have normal pigs.

9. Cod liver oil added in the basal ration promoted growth and the assimilation of the calcium present in the grains.

10. No obvious evidence of phosphorus deficiency appeared when a ration containing approximately 0 35% of phosphorus was used.

11. Under the conditions of the experiments under review a ration containing 15% of digestible crude protein and supplying an average of approximately 250 grams (0 55 lb.) of digestible crude protein daily per 100 lbs. live weight gave the most satisfactory results.

12. A daily calcium intake of 2.30 grams (0.135% of the ration) per 100 lbs. live weight maintained an apparently normal level of calcium in the blood serum and prevented the condition of "crippling" which developed in groups on a lower calcium intake, but did not provide sufficient calcium to bring about the most efficient utilization of the feed consumed.

13. Feeding ground limestone at a level which allowed for a daily intake of from 13–15 grams of calcium (0.72%–0.86% of the ration) appeared to be excessive. The necessity for further work in connection with varying the daily intake of calcium is indicated.

REFERENCES

1. HENRY and MORRISON. Feeds and Feeding—18th Edition.
2. ORR, J. B. The role of vitamins and minerals in stock feeding. Reprint from Journal of the Ministry of Agriculture, April and May, 1930.
3. DAVIDSON, H. R. Jour Agr. Sc. *20* : 233. 1930.
4. SPILDO, L. S. 151 de Beretning fra Forsogslaboratoriet. Kgl. Veterinaer—og Landbohojskoles Laboratorium for landokonomiske Forsog. Copenhagen. 1933.
5. BETHKE, EDINGTON and KICK. Jour. Agr. Res. *47* . 5. 1933.
6. SINCLAIR, R. D. Sci. Agr. *13* : 8. 1933.
7. ROBISON, R. Biochem. Jour. *17* : 286. 1923.
8. KAY, H. D. Jour Biol. Chem. *89* . 249. 1930
9. KAY, H. D. Brit. Jour. Exp. Path. *10* : 253. 1929.
10. JENNER and KAY. Brit. Jour. Exp. Path. *13* · 22. 1932.

Résumé

L'ADDITION DE PROTÉINE ET DE CALCIUM À UNE RATION DE MENUS GRAINS POUR LES PORCS D'ÉLÈVE. R. D. Sinclair et L. W. McElroy, Université de l'Alberta, Edmonton, Alta.

Les résultats de l'expérience qui est passée en revue dans ce travail peuvent donner lieu aux conclusions que voici.

Une ration de base, composée de blé, d'avoine et d'orge fournissant quotidiennement à peu près 175 grammes de protéine brute digestible et 0 5 gramme de calcium par 100 livres de poids vif, est insuffisante pour les porcs d'élève et d'engrais pesant de 50 à 200 livres, poids vif. Les porcs qui recevaient cette ration profitaient lentement, ils perdaient l'usage de leurs membres et ne faisaient pas un emploi économique de leur nourriture. Les porcs peuvent s'assimiler le calcium de la pierre à chaux broyée. L'addition de pierre à chaux broyée à la ration de base a provoqué le développement d'une ossature apparemment normale, activé la rapidité de croissance et facilité l'assimilation de nourriture. Lorsque la quantité de calcium fournie était insuffisante, les effets bienfaisants de l'addition de protéine à la ration de base étaient contrecarrés par le développement d'un état désigné "raideur" ou "impotence" chez les porcs. L'addition de pierre à chaux broyée à ces rations a empêché l'apparition de cette "raideur", encouragé la croissance et causé une utilisation plus économique de la nourriture. Lorsque le régime était déficitaire en calcium, la quantité de calcium dans le sérum du sang diminuait, mais il n'y avait pas de changements correspondants dans la proportion de phosphore inorganique. Cette faible proportion de calcium dans le sérum du sang était accompagnée d'un développement de "raideur" ou "d'impotence". L'emploi de pierre à chaux broyée dans l'alimentation a relevé le niveau de calcium dans le sérum du sang. Il a été constaté que le sang des porcs qui exhibent des symptômes cliniques d'un développement anormal des os, provenant d'un manque de calcium, contient une quantité plus grande de phosphatase que celui des porcs normaux. L'huile de foie de morue ajoutée à la ration de base a activé la croissance et l'assimilation du calcium présent dans les grains. Aucune preuve évidente d'un manque de calcium n'a été constatée lorsqu'on s'est servi de rations contenant environ 0 35% de phosphore. Dans les conditions de ces expériences, une ration contenant 15% de protéine brute digestible et fournissant en moyenne 250 grammes (0 55 liv.) de protéine brute digestible quotidiennement par 100 livres de poids vif, est celle qui a donné les résultats les plus satisfaisants. Une absorption quotidienne de 2 30 grammes (0 135% de la ration) par 100 livres de poids vif a maintenu un niveau apparemment normal de calcium dans le sérum du sang et prévenu "l'impotence" qui s'est développée dans les groupes qui faisaient une plus faible absorption de calcium sans fournir cependant suffisamment de calcium pour provoquer l'utilisation la plus efficace de la nourriture consommée. L'emploi de pierre à chaux broyée à un niveau qui permettait une absorption quotidienne de 13 à 15 grammes de calcium (0.72%-0.86% de la ration) paraissait être excessif. Les résultats acquis indiquent qu'il serait nécessaire de faire de nouvelles recherches sur les variations dans l'absorption quotidienne de calcium.

FECUNDITY AND NURSING CAPACITY OF LARGE YORKSHIRE SOWS

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In the spring of 1932 a project covering the collection of litter records was begun on the Dominion Experimental Farms. The objects of the experiment are as follows: first, to determine fecundity, litter mortality, and nursing capacity of brood sows, the latter characteristic being measured by the amount of gains of litters from birth to three weeks, since up to this age the litters are dependent upon their mothers' milk; secondly, to determine the variability of litters from the same sow in both size and gains; and thirdly, to determine the value of such data for rating sows and particularly boars. This paper is a report on the first phase of the work.

Source of Data

The data were obtained from the herds at Central Experimental Farm and fourteen Branch Farms located in the various Provinces of the Dominion. Considerable climatic variation exists between the various Experimental Farms; however, housing, feeding and management of brood sows are comparatively uniform, and hence litter records are reasonably comparable. Litters are born in all seasons, but the data were considered insufficient to warrant a classification by season. Moreover, Carmichael and Rice (*1*) found no noticeably regular influence of season on litter size or birth weight

Procedure

The data were collected on prepared forms which called for details of sire and dam, time and date of birth of litters, number born, total weight of both live and dead pigs at birth, and the weight of litters on the 21st day after initial weighing. The initial weights were taken ten to twenty-four hours after birth, which permitted all weighings during the working day, and excluded pigs that died within a few hours after birth from the initial live weight of litters. Dates and weights of pigs that died after initial weighing were also given.

Presentation of Data

The data are presented in the accompanying table classified according to the size of litter at three weeks, together with weighted averages of all litters. The range in litter size is from four to twelve pigs per litter, giving a total of nine classes, which will be referred to as the four class, five class, etc. There were a few litters of under four and over twelve pigs per litter alive at three weeks, but insufficient to warrant presentation. For comparative purposes the litter weights are given on a pig basis.

Number of Litters

There is a total of 410 litters, all of which are pure-bred Yorkshires. Of those alive at three weeks the nine class has the most with 75 litters. From the nine class the number of litters decrease very uniformly down to the six and up to the twelve class, indicating a normal distribution between these two numbers.

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TABLE 1.—LITTER DATA AVERAGES OF 410 YORKSHIRE LITTERS CLASSIFIED ACCORDING TO THE NUMBER ALIVE PER LITTER ON THE 21ST DAY OFTER BIRTH

Number born	Number of pigs alive 21st day	Birth weight	Weight 21st day	Average gains	C V. of litter gains	Number of mammae per sow	Number of litters
8 5	4	2 92	11 74	8 83	30 26	11 9	15
10 4	5	2 85	11 22	8 37	22 45	11 9	27
10 3	6	2 71	11 30	8 59	20 15	12 2	29
10 9	7	2 84	11 29	8 45	19 86	11 8	55
12 0	8	2 70	10 80	8 10	19 70	12 3	64
12 1	9	2 72	11 04	8 32	19 60	12 3	75
12 8	10	2 67	10 49	7 82	20 00	12 5	62
13 4	11	2 77	10 89	8 12	21 48	12 7	53
14 4	12	2 46	10 14	7 68	24 35	13 7	30
12 0	Wt. aver 8 5	2 68	10 87	8 19	20 92	12 3	

Number of Mammae per Sow

The number of mammae recorded were those functioning at the time of farrow. As would be expected the number per sow does not vary very much, since it is a general practice in selecting gilts for breeding to pay particular attention to this characteristic. However, the data presented show an increase in the average number of mammae from 11 9 in the four and five classes to 13 7 in the twelve class. In the ten and up classes the average number of pigs born exceeded the average number of functioning mammae. With regard to the inheritance of this characteristic Wentworth (*8*) has shown that there is correlation of 2626 ± 028 between the number of mammae of dams and offspring, while there is also a tendency of "triangle" and "suppressed" nipple variations to be transmitted. Wentworth and Lush (*9*) found that in crosses between wild boars and domestic sows the progeny tended to inherit the smaller number of mammae of the wild parents.

Number Born and Number Alive at Three Weeks

The Yorkshire breed has a reputation for prolificacy which is borne out by the records of these 410 litters. The average number born per litter is 12.0, with the range of 8 5 for the four class to 14.4 for the twelve class. The average number alive at three weeks is 8 5, a mortality of 29 2%. This mortality is greatest in the smaller litter classes, being over 50% in the four and five classes. Many of the pigs were born dead, others were weaklings and were killed. Some litters were too large for the sows to raise and thus some of the less vigorous ones were killed. There were also several accidental deaths.

Birth weight

In the majority of litters one or more pigs died between the time the birth weight was taken and the three-week weight; hence, the weight of those that died had to be deducted from the initial litter weight. This was done by deducting the actual weight of dead pigs when this was less than the average birth weight of the litter, and the average birth weight was deducted when the dead weight was greater than the average weight.

The birth weights correspond fairly closely to those given by Lush, Hetzer, and Culbertson (7) for American data, except that they are slightly heavier, largely due, probably, to the fact that for the present records the pigs were weighed ten to twenty-four hours after birth, and had, therefore, all been suckled. It can be noted that the birth weights gradually decrease, with slight variations, with the number born. In the four class with an average of 8.5 pigs born the average weight of the live pigs is 2.92 lb., while in the twelve class, with 14 4 pigs born, the birth weight is 2.46 lb.

The weight of the pigs born dead is not given because of the tendency of recorders to weigh in pounds and half pounds, which would thus give a large error when only one or two pigs are weighed. Lush et al (loc. cit.) found this tendency also in the records studied by them. These workers report, however, a lighter weight for pigs born dead, most likely owing to many of the pigs born dead having died several days before birth. They also found a slight sex difference, the males being slightly but significantly heavier than the females.

Weight Increase and Variation

As would be expected the three-week weight is larger for the smaller litters, there being a difference of 1.6 lb. between the four and the twelve classes. This difference shows up also in the gains, though to a slightly less extent. The average gains do not decrease quite uniformly from the four to the twelve class, which may be accounted for by the large variation there is in gains per litter. The greatest discrepancy is between the number nine, ten, and eleven classes. From the standpoint of the total weight of litters at three weeks the twelve class is the greatest, with 121 68 lb. per litter as against 119.79 lb. for the eleven class.

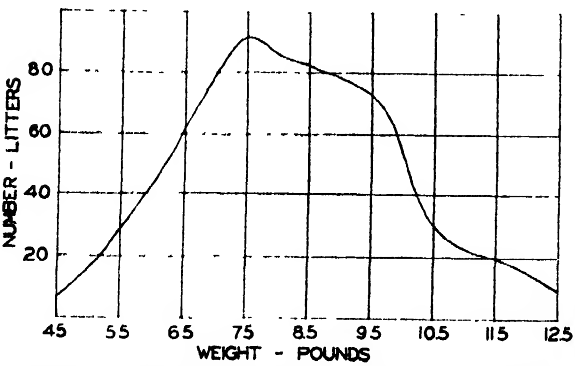

FIGURE 1. Distribution of gains per litter from birth to three weeks on a pig-per-litter basis.

The coefficient of variation was calculated from the pounds gain per litter from birth to three weeks. The average C.V. is 20.92% and there is little variation between the classes except in the twelve, and especially the four class. This is somewhat contrary to expectation as sows with smaller litters would be expected to give good and uniform gains. However, within the smaller litter classes are the poor lactating sows and unthrifty or weakling pigs, many of which die off before three weeks.

In order to present more clearly the variability in litter growth, the gains per pig per litter are presented graphically. There are 408 litters plotted, two extremes having been omitted that are included in the table, one a 3 lb. and the other a 15 lb. gain. As can be noted, the variations in gains are from 4 5 lb. to 12.5 lb. with a modal gain of 7.5 lb. per pig per litter.

Age of sows

The average age of the 410 sows was approximately 3.3 years at farrow. There was little variation in the average age of the different classes, except between the four and five classes, their respective ages being approximately 2.3 and 4.0 years. The age of sows is one of the factors which affects both birth weight and litter size. Thus Carmichael and Rice (*1*) found a fairly general increase in the birth weight of pigs as the sows grew older, while litter size only increased with the age of sows up to about three years. In a later study of the same herd Keith (*5*) found that in general the size of the litter increased with the age of the dam up to about 4.5 years, after which a gradual decrease occurred. Ellinger (*2*) found from a group of 134 sows of native Danish breed, each of which had ten litters, that the size of litters increased up to the sixth and seventh litter.

Time of Farrowing

Since the hour at which each sow farrowed was recorded it is of passing interest to mention some of the data. Only 19% of the sows farrowed between 7.00 A.M. and 2.00 P.M. The largest number farrowed late at night, 31% farrowing between 7.00 P.M. and midnight, and 73% between 2.00 P.M. and 4.00 A.M.

DISCUSSION

The records of these 410 litters show a large variation in the nursing capacity of sows as measured by the gains of litters to three weeks. For the more economical production of litters sows should be selected which raise litters of from nine to twelve pigs of average and above average gains. Improvement and maintenance of prolificacy and good nursing capacity depend, however, upon good breeding, feeding and management practices. As Hammond (*3*) points out, fecundity depends upon *(a)* the number of eggs shed which is mainly a matter of internal nutrition, although age is also a factor; *(b)* the number fertilized, which may be influenced by partial sterility of the boar; and *(c)* the number that develop properly, which mostly depends upon both nutritional and genetical factors. The time of service is considered to be an important factor in obtaining high fecundity. Krallinger and Schott (*6*), however, found insignificant differences in both litter size and percentage of fertile matings of early compared with late matings. In 46 sows served during the first few hours after the onset of heat, and 348 served mostly the following day, the litter size was respectively 9.8 and 10 05, and the percentage of fertile matings 63 0 and 65.8.

On a statistical investigation of the Large White breed in Sweden, Johansson (*4*) found that the correlation between litter size from the same sows was very low and insignificant. He concludes that sows should be selected on the basis of their having fourteen functional mammae and giving good litter gains, and secondarily upon litter size. Keith (*5*) however, found a significant correlation between the size of a given litter and the size of succeeding litters if a large enough number of individuals were used. It would appear, therefore, that the most effective way of identifying strains of high fecundity and good nursing capacity would be through progeny testing several daughters of each sire for these characteristics rather than placing too much emphasis on an individual sow's record. With the accumulation of more litter data the value of such a practice may be tested.

SUMMARY

1. Litter data is presented of 410 Yorkshire litters classified according to the number alive at three weeks, the range being from four to twelve pigs per litter.

2. The average number of functioning mammae of sows at farrow was 12.3; the number of pigs born 12.0; alive at three weeks 8.5; birth weight 2.68 lb.; weight on 21st day 10.87 lb.; and C.V. of gains from birth to three weeks 20.92%.

3. The number of mammae increased slightly and the average number of pigs born considerably from the four to the twelve class, while the average weights and gains decrease slightly, though not quite uniformly, from the four to the twelve class.

4. The problem of recognizing and selecting prolific strains of pigs is briefly discussed.

ACKNOWLEDGMENTS

For the collection of litter records acknowledgment is hereby made of the kind co-operation of the respective superintendents of the Experimental Farms and Stations located at Nappan, and Kentville, N.S.; Fredericton, N.B.; Cap Rouge, Ste. Anne de la Pocatiere, and La Ferme, Que.; Kapuskasing, Ont.; Brandon, Man.; Scott and Indian Head, Sask.; Lethbridge, and Lacombe, Alta.; Windermere, and Agassiz, B.C.

REFERENCES

1. Carmichael, W. J. and J. B. Rice. Variations in farrow: with special reference to the birth weight of pigs. Ill. Agric. Exp. Sta. Bull. 226. 1920.
2. Ellinger, T. The influence of age on fertility in swine. Proc. Nat. Academy of Sci. (U.S.) 7: 134-138. 1921.
3. Hammond, J. Fertility in pigs. Pig Breeders' Annual, London 1929-30.
4. Johansson, I. Problems in breeding for high prolificacy. Pig Breeders' Annual. London. 1931-32.
5. Keith, T. B. Relation of size of swine litters to age of dam and to size of succeeding litters. J. Agric. Res. *41*: 593-600. 1930.
6. Kralinger, H. F., and Schott. A Untersuchungen über Geschlechtsleben und Fortpflanzung der Haustiere II Der Einfluss des Decktermins innerhalb der Rausche der Schweine auf ihre Fruchtbarkeit und das Geschlechtsverhaltnis der Nachkommen. Arch. Tierernahrung und Tierzucht *9*: 41-49. 1933.
7. Lush, Jay L., H. O. Hetzer and C. C. Culbertson. Factors affecting birth weights of swine. Genetics *19*: 329-343. 1934.
8. Wentworth, E. N. Inheritance of mammae in Duroc Jersey swine. Amer. Naturalist *47*: 257-278. 1913.
9. Wentworth, E. N. and Lush, Jay L. Inheritance in swine. J. Agric. Res. *23*: 557-582. 1923.

Résumé

FÉCONDITÉ ET CAPACITÉ D'ALLAITEMENT DE GROSSES TRUIES YORKSHIRES. Alan Deakin et E. B. Fraser, Ferme expérimentale centrale, Ottawa.

Les données présentées couvrent 410 portées Yorkshires classées d'après le nombre de gorets en vie à l'âge de trois semaines, nombre qui variait de 4 à 12 sujets par portée. Le nombre moyen de trayons en fonctionnement chez les truies au moment de la mise-bas était de 12.3; le nombre de porcs nés, de 12.0; en vie, à trois semaines 8.5; poids à la naissance 2.68 liv.;poids au 21ème jour 10.87 liv.; et coefficient de variation de l'augmentation de poids à partir de la naissance jusqu'à l'âge de trois semaines, 20.92%. Le nombre de trayons augmentait légèrement tandis que le nombre moyen de porcs nés augmentait considérablement à partir de la classe de 4 sujets jusqu'à celle de 12; d'autre part, les poids moyens et les augmentations moyennes de poids diminuaient légèrement, mais non pas d'une façon très uniforme, à partir de la classe de 4 sujets jusqu'à celle de 12. Le problème de l'identification et du choix des espèces prolifiques de porcs est discuté sommairement.

THE EFFECT OF FULL VERSUS LIMITED FEEDING ON THE PROTEIN LEVEL REQUIRED IN THE HOG RATION[1]

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INTRODUCTION

The question of the optimum level of protein in the diets of hogs intended for bacon production is one on which investigators differ. That rate of growth and economy of feed may be adversely affected by too meagre a protein intake is generally admitted. The possibility, however, that the protein requirements of pigs may in some measure be correlated with total food intake, and hence that under full feeding the proportion of protein to carbohydrate equivalent may be different to that which is optimum where limited feeding is followed, has not been investigated. And since most of the hog feeding of eastern Canada would be classed as "limited," while the majority of feeding trials on which hog feeding recommendations are based have involved full feeding, it seemed advisable to obtain information as to whether or not this difference in feeding practice would need to be taken into account in interpreting results. Accordingly, a feeding trial was undertaken in July, 1933, the results of which are herein reported.

The object of the experiment was to study the effects on rate of gain in live weight, and on the type of hog and hog carcass produced by different levels of protein in the diet when full fed as compared to limited feeding.

METHODS

Plan

The allotment of pigs to the several feeding lots in so far as the protein levels were concerned was a matter of standard routine. With regard to the full and limited feeding, it was decided to pair the pigs at allotment, one pig of each pair to be full-fed while the pair mate was to receive at each feeding half the quantity given the full-fed pig. Thus the consumption of the full-fed pig became the gauge for what was to constitute limited, or half feeding.

Allotment

Forty Yorkshire pigs were grouped at weaning time into 20 pairs, so that considering weight, condition, thrift, age, breeding, and sex, the pair mates were as nearly alike as possible. The ages ranged from 59 to 62 days. Out of the 20 pairs, six were not of the same sex and seven were not littermates. All were sired by the same boar, and the dams were sisters or half-sisters. In no case did pair mates differ by more than four pounds in initial weight (see Table 1).

Once the pairings were made, the pairs were allotted at random to each of the five lots. The subsequent separation of the pair mates of a lot into the sub-lot groups as 1 or 1a, 2 or 2a, etc., was determined by flipping a coin.

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This allotment procedure was followed (1) in order to obtain a random allotment between and within lots receiving rations of different protein levels, and (2) at the same time to preserve as close a similarity as possible between half and full-feed pair mates.

Rations Fed and Feeding Practice

All pigs were individually penned and hand fed throughout the trial. The dry meal allowance was measured into the trough and the water allowance poured over it.

The composition of the basal ration and of the protein-mineral supplement was the same for all lots throughout the trial. The former consisted of equal parts of corn (or hominy) and barley. The supplement was compounded as follows:—

40.0 lb. Tankage
20.0 lb. Linseed oilmeal
20.0 lb. Fishmeal
12.5 lb. Bone char
4.0 lb. Wood charcoal
1.0 lb. Cod liver oil
2.0 lb. Salt
0.5 lb. Ferric oxide

100 lbs.

This supplement carried 43.4% protein. The charcoal was included only as a carrier for the cod liver oil.

The proportion of the basal and supplement fractions of the rations differed between each of the five lots, not only at the start of the trial but during the successive feeding periods. These periods were as follows:—

Weanling period—first 30 days of the test.
Growing period—second 30 days of the test.
Fattening period—third 30 days of the test.

TABLE 1.—DETAIL OF RATIONS FED BY PERIODS AND INITIAL WEIGHTS OF PIGS AS ALLOTTED

Lot	Percent protein supplement in rations			Level of feeding	Live weights of pigs at allotment				
	Weanling period	Growing period	Finishing period		Pigs 1	2	3	4	Average of group
1	30	20	10	Full	23	49	42	32	36.5
1a				Half	22	47	42	32	35.8
2	30	10	10	Full	25	27	27	31	27.5
2a				Half	25	27	27	31	27.5
3	20	20	10	Full	27	30	30	38	31.3
3a				Half	23	29	28	37	29.3
4	20	10	10	Full	25	33	30	31	29.8
4a				Half	26	30	30	30	29.0
5	10	10	10	Full	19	35	27	33	28.5
5a				Half	19	41	26	34	30.0

Table 1 gives the detail of the proportions of protein supplement in the rations of the several lots for each feeding period.

Gains of pigs and their feed consumptions were recorded for each of these 30-day periods. Where necessary to extend the feeding period beyond the 90 days, the rations of the fattening period were continued. In this trial all lots remained on feed an extra 14 days.

After this time (104 days of feeding) all full-fed pigs (excepting one at 187 lbs.) had reached 190 lbs. or more, and were, therefore, removed from test. The removal of the full-fed pigs removed the guides for what constituted "half feed." Consequently, the remaining pigs were then full fed to market weight.

Statistical Reduction of Data

The allotment of animals and organization of the trial was so done that the data could be analysed statistically, using the method of partial regression[2] to correct the observed gains in weight for the effects of differences in the initial weights of the animals at the start of any feeding period and for the effects of differences in feed intake. This procedure makes possible the best estimate of gains to be expected had all animals been of equal weight at the beginning of the feeding and had they eaten equal quantities of feed. Hence, gains so adjusted will, within the limits of experimental error, be a direct expression of the efficiency of the respective rations on which they were produced.

In Tables 2a, 3a, and 4a, the relative gains shown are based on the general mean gain of all lots during the period in question. These figures represent the relative efficiency of the several rations in producing live weight increases on pigs according to the percentage protein of the rations and the level of feed intake (full versus half fed).

Observations During the Trial

After from three weeks to a month of feeding, three of the pigs showed signs of diarrhoea and the faeces of several others were quite soft. The three pigs and their pair mates were removed from the trial and replaced with other pairs. One of the replacements (Lot I, pig No. 15) later suffered from diarrhoea so that the data from that pair were deleted from the trial.

This condition could not be explained unless it was the result of the cod liver oil in the rations. It could not have been connected with protein level or with full or half feeding, since the symptoms (soft faeces) occurred as often in one group as another. Furthermore, the same feeds excepting the cod liver oil had been fed for several years without such symptoms occurring. There did not appear to be any inflammation or irritation, and the faeces though soft were of normal color. The pigs seldom went off feed. In all cases, excepting the four above mentioned, the condition cleared up after two or three weeks.

RESULTS

The presentation of the results of this study will be more clearly made if each period is first considered by itself. For complete data the reader is referred to the appendix.

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[2] See Crampton and Hopkins. The use of the method of partial regression in the analysis of comparative feeding trial data. Part I. J. Nutrition, 8 : 1. July, 1934. Part II. J. Nutrition, 8 : 3. September, 1934.

Throughout this report references to protein level are in terms of the proportions of the mixed protein-mineral supplement to basic feeds. In terms of total crude protein (N × 6 25) of the complete diets, the equivalents are as follows:

30% protein supplement gave a ration carrying 20% crude protein.
20% protein supplement gave a ration carrying 17% crude protein.
10% protein supplement gave a ration carrying 14% crude protein.

Weanling Period (First 30 Days from Weaning)

The actual average daily gains made during the weanling period by the pigs, and the relative gains, to remove effects of differences in initial weight of pig and unequal feed intake, are given in Table 2.

TABLE 2.—AVERAGE RATE OF GAIN (IN LBS.)—WEANLING PERIOD (30 DAYS)

Lots		I	II	III	IV	V	Average half and full feed
Protein supplement in ration, %		30	30	20	20	10	
Average daily gain	Full fed	1 02	1 16	1 06	1 23	83	1 06
	Half fed	69	72	70	67	42	64

TABLE 2A. RELATIVE GAIN (IN LBS) ADJUSTED TO EQUAL FEED INTAKE AND CONSTANT INITIAL WEIGHT OF PIG

Lots		I	II	III	IV	V	Average half and full feed
Protein supplement in ration, %		30	30	20	20	10	
Relative gains	Full fed	103	116	98	113	76	101
	Half fed	109	104	102	100	78	99

Rate of Gain

In so far as the rate of gain is concerned, it is at once evident that full feeding resulted in about 60% faster gains than half feeding, regardless of level of protein of the diet. In judging the effect of protein level, Lots I and II should be averaged, since both were on rations containing the same percentage of protein supplement. Similarly, Lots III and IV must be taken together. Between Lots I, II, III, and IV, there was practically no difference with the half-fed pigs. Lot V, however, in which the protein supplement constituted but 10% of the ration during the weanling period, showed markedly slower gains.

With the full feeding it appears that the 20% supplement lots (Lots III and IV) had a slight advantage over the 30% supplement rations (Lots I and II). As with the limited feeding, the pigs in Lot V gained decidedly slower than those of the other groups on the same feeding practice.

Efficiency of Ration

The relative efficiency of the several rations fed cannot be directly measured by the rate of gain made by the pigs, since these gains are

materially affected by the quantity of feed eaten and to a lesser extent by the initial weights of the pigs. In order to eliminate these two factors, the actual gains were corrected statistically for differences in feed intake and varying initial weight and then expressed as a percentage of the general average gain of all lots. These relative gains are directly comparable and represent the best estimate obtainable from the data of the relative nutritive values of the rations fed.

When presented in this way, it becomes clearly evident that no differences can be claimed between half and full feeding in so far as efficiency of the rations is concerned, and this regardless entirely of level of protein intake. In other words, no increased efficiency of the nutrients of the rations is realized by limited as compared to full feeding during the weanling period.

In the matter of protein level, there appears to be no significant difference between the rations carrying 30% and those consisting of 20% protein supplement. Lot V, however, in which the mixture contained but 10% protein supplement, showed significantly (P= 05) smaller gains per unit feed eaten. The difference is quite clear cut. In so far as the weanling period is concerned, therefore, it would appear that with the protein supplement used in this study, this fraction of the ration need not exceed 20% but should be larger than 10%. (Equivalent to 17% and 14% crude protein respectively).

Growing Period (Second 30 Days from Weaning)

The data for the second 30 days of feeding have been recorded and analyzed independently by the same methods described for the weaning period. The results are shown in Tables 3 and 3a.

TABLE 3.—AVERAGE RATE OF GAIN (IN LBS.)—GROWING PERIOD (30 DAYS)

Lots		I	II	III	IV	V	Average half and full feed
Protein supplement in ration, %		30	10	20	20	10	
Average daily gain	Full fed	1 69	1 55	1 86	1 92	1 48	1 70
	Half fed	1 06	99	1 34	1 06	92	1 07

TABLE 3A.—RELATIVE GAIN (IN LBS) ADJUSTED TO EQUAL FEED INTAKE AND CONSTANT INITIAL WEIGHT OF PIG

Lots		I	II	III	IV	V	Average half and full feed
Protein supplement in ration, %		30	10	20	10	10	
Relative Gains	Full fed	95	86	101	103	92	95
	Half fed	103	95	119	106	105	105

It will be noted, however, that for this period the proportions of protein supplement have been reduced in all lots excepting Lots III and V, in which they have remained the same as in the previous period.

Rate of Gain

The daily gains (Table 3) of the full-fed pigs are, on the average, 59% faster than those of the half-fed groups. The pigs in Lots III and IV, full-fed, appear to have made somewhat more rapid progress than the others. These lots were previously both on diets containing 20% supplement. It is possible that the reduction from 30% to 20% in Lot I and to 10% in Lot II was drastic enough to have caused a check in the gains of these lots as compared to Lot III, which remained on 20% supplement. On the other hand, the reduction in supplement from 20% to 10% in the case of Lot IV did not reduce the gains in this lot over those of Lot III. Furthermore, in the half-fed groups, while Lot III is still the best, the gains in Lot I are the same as in Lot IV. Lot V, as during the weanling period, made slowest gains of all.

Efficiency of Rations

When corrections for variations in initial weight of pigs (which now, because of the intervention of the 30-day weanling period between the original allotment and this feeding period, was considerable), and differences in quantity of feed eaten, the relative standing of the groups is somewhat different (Table 2a). Lots III and IV, which started on 20% supplement, are in the first place, while Lot V is about the same as Lots I and II. Also the half-fed pigs of all lots made slightly more efficient use of their rations than did the full-fed pigs. Statistically the half-fed group of Lot III was significantly higher than any other group. The other differences were not significant as measured by odds of 20 to 1.

Fattening Period (Third 30 Days after Weaning)

Rate of Gain

Data for the third 30 days of feeding, during which the rations for all lots were reduced to 10% of supplement, are shown in Tables 4 and 4a. Again the full-fed pigs gained about 60% faster than their half-fed pair mates. The gains in the different lots, however, were quite similar during this period.

TABLE 4.—AVERAGE RATE OF GAIN (IN LBS.) FATTENING PERIOD (30 DAYS)

Lots		I	II	III	IV	V	Average half and full feed
Protein supplement in ration, %		10	10	10	10	10	
Average daily gain	Full fed	2 19	2.09	2 07	2.29	2.03	2.13
	Half fed	1 30	1 38	1 29	1 37	1.38	1 32

TABLE 4A. RELATIVE GAIN (IN LBS.) ADJUSTED TO EQUAL FEED INTAKE AND CONSTANT INITIAL WEIGHT OF PIG

Lots		I	II	III	IV	V	Average half and full feed
Protein supplement in ration, %		10	10	10	10	10	
Relative gains	Full fed	104	102	99	106	108	104
	Half fed	94	98	94	98	98	96

Efficiency of Ration

When corrected for initial weight and feed intake, there was not a significant difference found either between half and full feeding or between lots. On the average the full-fed pigs made slightly more efficient use of the rations.

Total Feeding Period (104 Days)

As already mentioned, in order to bring the full-fed pigs to market weight an additional 14 days of feeding beyond the three 30-day periods, already discussed, was necessary, thus giving a total of 104 days. The data for the total period (104 days) are summarized in Tables 5 and 5a.

TABLE 5.—AVERAGE RATE OF GAIN—ALL PERIODS (104 DAYS)

Lots		I	II	III	IV	V	Average half and full feed
Average daily gain	Full fed	1 72	1 67	1 72	1 88	1 54	1 71
	Half fed	1 05	1 07	1 14	1 08	93	1 02

TABLE 5A.—RELATIVE GAIN ADJUSTED TO EQUAL FEED INTAKE AND CONSTANT INITIAL WEIGHT OF PIG

Lots		I	II	III	IV	V	Average half and full feed
Relative gains	Full fed	101	96	97	104	96	99
	Half fed	102	100	105	102	97	101

Rate of Gain

As to full and half feeding, we find some 67% faster gains with the full feeding. The slowest gains in both full and half-fed groups were made by Lot V, which remained throughout on the 10% protein supplement. Attention might also be called to the very satisfactory rates of gain made by the full-fed pigs, averaging as they did 1 71 lbs. per day. Even the pigs of Lot V made better than one and a half pound per day gain. The limited feeding resulted in just about one pound gain per day, which is close to the average results reported under farm conditions.

Efficiency of Ration

When placed on a relative basis and the effects of feed intake and initial weight removed, there is no appreciable difference shown between full and half feeding in gains per unit feed eaten. Nor did there appear to be any difference between Lots I, II, III, or IV as the result of the different levels of protein intake. There was, however, just a suggestion that the diet of Lot V, which included 10% protein supplement throughout the 104 days, was slightly less efficient than that of the other lots. Statistically none of these differences could be counted significant.

Market Grading

As mentioned previously, after 104 days of feeding, the full-fed pigs were practically ready for market. When these pigs were removed the remaining groups were put on full feed. An attempt was made to market all pigs as they were finished. It was not possible, however, to arrange for shipment or slaughter of pigs individually, and hence some variations were unavoidable in shipping weights. The average days each lot was on feed, the shipping weights, and the live grading of the hogs on the market are shown in Table 6.

TABLE 6.—SUMMARY OF MARKET GRADING ON HOOF

Lot	Per cent protein supplement by periods	Grading on hoof											
		Full-fed pigs						Half-fed pigs					
		No pigs	No Select	No Bacon	No Heavy	Av wt	Days on feed	No pigs	No Select	No Bacon	No Heavy	Av wt	Days on feed
1	30–20–10	3	3	—	—	211	108	3	1	1	1	227	145
2	30 10 10	4	2	2	—	204	107	4	2	2	—	218	133
3	20-20–10	4	4	—		217	107	4	2	2	--	213	134
4	20–10 10	3	2		1	232	108	3	1	1	1	233	135
5	10 10–10	4	2	1	1	213	122	3	2	1	–	213	172
Av (in per cent)			68.8	18.8	12.5	214	110.5		47.0	41.2	11.8	220	142.6

It should be mentioned that two pigs from Lot III and one from Lot V were kept for breeding; one pig, Lot I, died during the trial, thus eliminating his mate on half feed; and one pair in Lot IV became mixed and was, therefore eliminated. These pigs were not included in the marketing data.

From Table 6, it is evident that full feeding did not result in any penalty as to type of pig as indicated by classification into "selects," "bacons," or "heavies." There were 13 selects, 3 bacons and 2 heavies in the full-fed group as against 8 selects, 7 bacons, and 2 heavies among the half-fed lots.

Further evidence that full feeding does not adversely affect the finished product is shown in the rail grading record and the measured carcass length (1st rib to aich bone). These data are given in Table 7.

Attention might be directed to the fact that neither the rations nor the level of feeding had the slightest effect on the length of the pig. Nor did full feeding result in a lower percentage of the carcasses grading as Wiltshires. In the case of the half-fed pigs the fact that, because of greater irregularity in reaching market condition, they were fed to slightly heavier weights on the average probably accounts for the poorer showing in the rail grading.

TABLE 7.—AVERAGE LENGTH OF CARCASS AND PERCENT WILTSHIRE SIDES

Lot	Percent protein supplement by periods	Average length (inches) 1st rib to aich bone		Percent Wiltshire*	
		Full-fed	Half-fed	Full-fed	Half-fed
1	30–20–10	31 8	31 6	100	66
2	30–10–10	32 3	33 0	100	50
3	20-20–10	31 8	32 4	100	50
4	20–10–10	33 0	32 3	100	33
5	10–10–10	32.9	32 2	75	66
Average		32 4	32.4	93 7	52 9

*Rail grading by Wilsil Company.

SUMMARY AND CONCLUSIONS

In this trial comparisons were made between the rate of live weight gains, ration efficiency, and excellence of market hog produced by full feeding versus half feeding with rations containing different proportions of a mixed protein-mineral supplement, the latter being reduced periodically according to the plan shown in Table 8. This table also summarizes by lots and feeding periods the gains and gains corrected to constant feed intake and initial weights. In each lot half the pigs were full fed and the remainder fed half the amount eaten by the full-fed section. The results of the trial would seem to justify the following conclusions.

1. Using the feed mixtures reported in this test, the rations for market pigs for the first 30 days after weaning need not contain more than 17% total crude protein, regardless of whether pigs are full or half fed. (Lots III and IV.)

2. During the next 30 days the crude protein level of the ration under full feeding may be reduced to 14% (Lot IV). Under half feeding there is some evidence to suggest that faster gains and slightly greater feed efficiency may be expected if the protein level of the weanling period (17%) is continued through this second 30 days (Lot III).

3. After the first 60 days, all lots were fed rations carrying 14% of crude protein The group (Lot IV) which started at weaning on the ration containing 17% of protein and changed after 30 days to a ration of 14% protein continued to show equally efficient and at the same time the fastest gains of any

4. Over the whole period, weaning to market weight, the Lot IV, full-fed pigs, showed the best results. With half feeding, Lot III stood first by a slight margin over Lot IV.

5. A ration for weanling pigs containing only 14% crude protein does not contain sufficient protein for optimum growth. (Lot V.)

6. The efficiency of the rations in producing live weight gains was not affected by half versus full feeding. Full feeding, however, resulted for all periods and in all lots in 60% faster gains.

7. When marketed at the same live weight (about 200 lbs.), full feeding did not adversely affect the market grading either on the hoof or on the rail. There was actually a larger percentage both of "selects" and of Wiltshire sides from among the full-fed than half-fed hogs.

TABLE 8.—MEAN GAINS AND GAINS CORRECTED FOR VARYING FEED INTAKE AND INITIAL WEIGHT

Lot No.	Percent crude protein in diets by periods			Level of feeding	Weanling period 1st 30 days		Growing period 2nd 30 days		Finishing period 3rd 30 days		Total period 104 days	
	1st 30 days	2nd 30 days	Balance of period		Average daily gains	Corrected gains*	Average daily gains	Corrected gains*	Average daily gains	Corrected gains*	Average daily gains	Corrected gains*
I	20	17	14	Full	1 02	26 3	1 69	39 5	2 19	54 1	1 72	145 0
				Half	69	27 9	1 06	42 8	1 30	48 6	1 05	146.7
II	20	14	14	Full	1 16	29 6	1 55	35 8	2 09	53 0	1 67	138 1
				Half	72	26 5	99	39 7	1 38	50 6	1 07	142 7
III	17	17	14	Full	1 06	24 9	1 86	41 9	2 07	51 5	1 72	139 5
				Half	70	26 1	1 34	49 5	1 29	48 5	1 14	150.6
IV	17	14	14	Full	1 23	28 9	1 92	43 0	2 29	54 7	1 88	148 7
				Half	.67	25 6	1 06	44 1	1.37	50 6	1 08	145 9
V	14	14	14	Full	83	19 5	1 48	38 3	2 03	56 1	1 54	138.4
				Half	42	19 9	92	41 7	1.28	50 7	.93	138.9
Mean feed (all lots)					71 1 lbs.		125.5 lbs.		172 8 lbs.		463.2 lbs.	
Standard errors of corrected gains					± 4 00 lbs.		± 4 53 lbs.		± 6 42 lbs.		± 13 01 lbs.	

Résumé

L'EFFET D'UNE ALIMENTATION ABONDANTE ET D'UNE ALIMENTATION LIMITÉE SUR LA QUANTITÉ DE PROTÉINE NÉCESSAIRE DANS LA RATION DES PORCS. E. W. Crampton, Collège Macdonald, P.Q.

Ce bulletin couvre une étude des effets d'une alimentation abondante et limitée sur le niveau de protéine nécessaire dans la ration des porcs, indiqué par la rapidité de croissance du porc, l'efficacité de l'utilisation de la nourriture et le classement pour le marché des animaux en vie et habillés. Les résultats indiquent que les rations pour les porcs sevrés ne doivent pas contenir plus de 17% de protéine brute et que ce niveau peut être abaissé à 14% après les premiers 30 jours d'alimentation. Lorsque la proportion de protéine dans la ration des porcs sevrés descend jusqu'à 14% la quantité de grains par unité de nourriture consommée subit une forte diminution. La quantité de nourriture n'a exercé aucune modification sur les effets des différents niveaux de protéine dans la ration. Cependant, quel que soit le niveau de protéine, l'alimentation abondante a provoqué une augmentation de poids de quelque 60% plus rapide. La quantité de nourriture n'a exercé aucun effet sur la longueur du corps, pas plus que sur le classement pour le marché des animaux en vie ou habillés.

APPENDIX

Appendix Table 1. Weights, gains, and feed consumption of pigs Lot 1

	Pig No.	Weanling period			Growing period		Finishing period		Total 104 days	
		Initial weight	Gain	Feed	Gain	Feed	Gain	Feed	Gain	Feed
Full-fed	75	23	30	76	42	120	55	183	158	485
	151	49	20	83	—	—	—	—	—	—
	120	42	38	100	59	213	62	268	182	721
	107	32	34	90	48	159	74	248	186	634
	Mean	36.5	30.5	87.3	49.7	164	63.7	233	175.3	613.3
Half fed	92	22	22	46	38	80	47	122	114	308
	146	47	18	55	33	89	—	—	—	—
	142	42	19	56	30	96	31	119	94	341
	112	32	24	57	35	92	39	122	110	328
	Mean	35.8	20.7	53.5	32.8	89.3	39	121	106	325.7

Appendix Table 2.—Weights, gains, and feed consumption of pigs. Lot II

	Pig No.	Weaning period			Growing period		Finishing period		Total 104 days	
		Initial weight	Gain	Feed	Gain	Feed	Gain	Feed	Gain	Feed
Full-fed	89	25	35	79	48	156	66	206	191	568
	74	27	30	73	46	151	62	203	169	552
	113	27	34	95	46	175	63	254	166	657
	95	31	40	90	46	167	60	237	167	611
	Mean	27.5	34.8	84.3	46.5	161.5	62.8	224.8	173.3	597.0
Half-fed	91	25	20	54	24	81	38	118	107	316
	71	27	19	51	26	82	35	115	106	312
	97	27	23	56	32	98	45	135	113	347
	108	31	24	57	37	105	47	130	118	344
	Mean	27.5	21.5	54.5	29.8	91.3	41.2	124.5	111.0	329.8

Appendix Table 3.—Weights, gains, and feed consumption of pigs. Lot III

	Pig No.	Weaning period			Growing period		Finishing period		Total 104 days	
		Initial weight	Gain	Feed	Gain	Feed	Gain	Feed	Gain	Feed
Full-fed	93	27	23	84	49	143	60	212	172	564
	79	30	28	83	54	150	72	217	185	566
	98	30	40	100	63	200	67	237	198	684
	129	38	36	100	57	201	49	242	160	674
	Mean	31.3	31.8	91.8	55.8	173.5	62.0	227.0	178.8	622.0
Half-fed	86	23	21	53	36	83	35	114	112	312
	72	29	21	56	36	83	41	119	132	324
	102	28	22	55	50	109	40	132	128	351
	145	37	20	57	39	100	39	116	111	339
	Mean	29.3	21.0	55.3	40.3	93.8	38.8	120.0	120.8	331.5

Appendix Table 4.—Weights, gains, and feed consumption of pigs. Lot IV

	Pig No.	Weanling period			Growing period		Finishing period		Total 104 days	
		Initial weight	Gain	Feed	Gain	Feed	Gain	Feed	Gain	Feed
Full-fed	90	25	37	89	55	160	66	240	191	600
	73	33	38	92	59	172	70	251	202	647
	111	30	40*	98*	–	–	–		–	–
	101	31	34	98	55	177	69	228	189	640
	Mean	29.8	37.3	94.3	56.3	169.7	68.3	239.3	194.0	629.0
Half-fed	81	26	22	54	37	77	38	111	120	304
	85	30	10	50	20	63	39	123	95	311
	115	30	16*	54	–		–		–	–
	106	30	25	57	38	103	47	129	126	350
	Mean	29.0	18.3	53.8	31.7	80.3	41.3	120.7	113.7	321.7

*Estimated values

Appendix Table 5. Weights, gains, and feed consumption of pigs Lot V.

	Pig No	Weanling period			Growing period		Finishing period		Total 104 days	
		Initial weight	Gain	Feed	Gain	Feed	Gain	Feed	Gain	Feed
Full-fed	87	19	18	56	23	74	11	126	111	329
	70	35	32	100	57	182	76	237	203	651
	109	27	19	71	45	138	63	202	161	542
	104	33	31	121	52	194	60	228	167	663
	Mean	28.5	25.0	88.0	44.3	147.0	60.8	198.3	160.5	547.0
Half-fed	88	19	15	47	18	54	22	64	71	209
	76	41	14	57	35	86	44	130	114	337
	83	26	7	45	18	70	39	110	83	286
	100	34	14	48	39	99	48	130	117	335
	Mean	30.0	12.5	49.3	27.5	7[illegible].0	38.3	108.5	96.3	291.8

DIGESTIBILITY STUDIES WITH RUMINANTS. 1. PLANE OF NUTRITION AND DIGESTIBILITY OF HAY

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INTRODUCTION

The possible existence of factors affecting the determination of coefficients of digestibility of feeding stuffs has long been recognized. Such factors may include: *(a)* the plane of nutrition; *(b)* the associative effects of feeds; *(c)* the age of the animals; and *(d)* the species. Very little has been accomplished, however, towards definitely assessing the importance and magnitude of these factors.

Accordingly, a study has been commenced on the significance of the coefficients of digestibility of feeding stuffs when determined under certain specific conditions. Attention will be given primarily to the effect of the plane of nutrition and of the association of feeds. The present paper deals with the relation of the level of feeding to the digestibility of a mixed clover and grass hay.

LITERATURE

Data furnishing information concerning the effect of the plane of nutrition upon the digestibility of a roughage for ruminants are found in the published works of the following investigators: Armsby and Fries (*1*, *2*, *3*, *4*, *5*, *6*), Armsby, Fries and Braman (*7*), Forbes, Fries and Braman (*8*), Henneberg (*9*), Henneberg and Stohmann (*10*), Honcamp and Gschwindner (*11*), Honcamp and Koch (*12*), Wolff, Funke and Kreuzhage (*14*), Wolff, Funke, Kreuzhage and Kellner (*15*).

The data taken from the reports of Armsby and his co-workers and Forbes and his co-workers were incidental to their investigations on energy metabolism. Usually one and sometimes two animals only were used at two or three levels of nutrition. Definite conclusions cannot, therefore, be drawn from their work except to say that, at the most, a change in the level of feeding produced relatively small changes in the digestibility of a roughage.

Similarly, the other investigations cited were characterized, as a general rule, by a lack of sufficient data from which satisfactory conclusions could be drawn. For example, in the works of Henneberg, and Henneberg and Stohmann, the hays were fed at the two levels of approximately 20 and 25 pounds per 1,000 pounds live weight. These quantities represented close to the upper limit of the capacity of the animals and ignored all other levels. In the investigations of Wolff, Funke and Kreuzhage, the different levels of feed were given to three different breeds of sheep of widely varying live weights. Per unit weight of animals the rations were all approximately the same.

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Honcamp and his collaborators conducted an extensive investigation on the effect of the plane of nutrition upon the digestibility for both roughages and productive rations. The experiments with roughages were conducted in duplicate using sheep as experimental animals. In the later publication cited above, the digestibility showed a slight decrease at the higher levels of feeding. It was not possible, however, to estimate the significance of this. The authors, as a matter of fact, concluded that, except in the case of the crude fibre, the changes were not significant.

Generally, the results of these various investigations would seem to indicate that the plane of nutrition had no very marked effect upon the digestibility of dried roughages. In view of the uncertainties in regard to the conclusions, a further investigation of this question was deemed advisable.

EXPERIMENTAL

Digestion trials were conducted on a mixed clover and grass hay with four grade Shorthorn steers. At the beginning of the experiment, in November, 1933, the animals were a little over two and one-half years old and averaged 985 pounds in weight. The experiment was concluded in April, 1934.

The experiment was divided into five periods, each of which consisted of a preliminary period of 13 days followed by a collection period of 12 days. The collection period was divided into 3 equal subperiods during each of which the feed and excrement were composited and analyzed. In addition, during the last 4 days of the preliminary period, a composite sample was taken of the hay for analysis. The schedule of feeding is given in Table 1.

TABLE 1.—WEIGHTS OF HAY FED TO ANIMALS IN KILOGRAMMES PER ANIMAL PER DAY

Period	Dates	Kilogrammes of hay per day			
		Animal 20023K	Animal P24396	Animal P24402	Animal 276L
1	20 11 33 to 19 12 33	4 5	6 0	7 5	9 0
2	19 12 33 to 16 1 34	6 0	4 5	9 0	7 5
3	16 1 34 to 13 2 34	9 0	7 5	6 0	4 5
4	13 2 34 to 13 3 34	7 5	9 0	4 5	6 0
5	13 3 34 to 10 4 34	2 5	2 5	2 5	2 5

It will be observed that the hay was fed at levels of 2 5, 4 5, 6 0, 7.5 and 9.0 kilogrammes per animal per day The level of 9 0 kilogrammes represented the limit of the capacity of the animals. In fact, in the cases of animals P24402 and P24396 at this level, hay was refused to the amounts of 3.625 and 8 053 kilogrammes, respectively, for the 12-day period.

The accuracy of coefficients of digestibility determined under the conditions where there are feed refusals is governed by the following factors: *(a)* percentage of feed refused; *(b)* regularity of feed refusals;

and (c) similarity of the compositions of the feed refused and the feed offered. In this connection, for this experiment, the refusals amounted to 3 4% and 7 46%, respectively. As far as the comparative compositions of the refused and offered hay were concerned, chemical analyses are given in Table 2 for the feeding stuffs involved.

TABLE 2.—CHEMICAL COMPOSITIONS ON DRY MATTER BASIS OF HAYS OFFERED AND REFUSED AT THE 9 0 LEVEL

Nutrient	Animal P24402			Animal P24396	
	Hay offered	Hay refused (1)	Hay refused (2)	Hay offered	Hay refused
Organic matter	92 53	92 68	92 21	92 53	92 76
Crude protein	10 47	9 17	10 55	9 96	8 52
Ether extract	2 21	3.27	2 36	2 29	2 32
Crude fibre	35 83	36 42	36 16	37 11	38 47
N-free extract	44 07	43.81	43 13	43 18	43 36

It will be seen from Table 2, that the compositions of the hays refused resembled those of the hays offered. The crude protein, however, for sample No. 1 in the case of animal P24402 and for animal P24396 was slightly low. Both from these analyses and from actual observation it was felt that the refusals were due to the limit of the capacity of the animals and not due to discrimination against woody portions of the feed.

The refusals were reasonably regular throughout the trial. As an arbitrary method of computing them in relation to the excretion of the feces, the amount was calculated from 3 days preceding the beginning to 3 days preceding the end of the collection period The refusals, however, commenced shortly after the start of the preliminary period and continued to the completion of the weighing of the animals, namely, until the third day after the completion of the collection period.

In view of the above considerations, therefore, it was felt that the coefficients of digestibility determined for these two animals at the level of 9 0 kilogrammes were reliable. A check on this assumption would, of course, be furnished by the data obtained on the other two animals where the hay was completely consumed.

In regard to the orientation of the digestion trials, as will be seen from Table 1, the levels of from 4.5 kilogrammes to 9.0 were so arranged that in any one period each animal received a different level. This eliminated any possible effect of a seasonal variation throughout the winter. The level of 2.5 kilogrammes was, however, undertaken simultaneously for all the animals. This quantity of feed represented a condition of semi-starvation. Since no information was at hand concerning the effects of starvation upon an immediate subsequent determination of coefficients of digestibility it was not felt advisable to include this level with the others. For that reason, the results obtained therefrom may, theoretically, lack something of the definiteness of those obtained from the other four levels. From the data obtained in the first four trials, however, information could

be obtained as to whether or not the digestibility was constant throughout the course of the different trials.

For the purpose of the experiment, ten tons of hay were cut with a corn cutter and blown into the barn loft. A sufficient quantity for each trial was selected, mixed thoroughly and stored in the experimental feed bins. Each period was treated as a separate digestion experiment and the analyses of the hay for any one period were related to the calculation of the coefficients of digestibility for that period only.

Iodized salt was furnished at the rate of 28 grammes per animal per day for the first four periods. In the fifth period, representing the level of 2.5 kilogrammes, it was placed before the animals as pressed blocks. In this latter case, the consumption for animals 20023K and P 24396 remained substantially the same. Animals P24402 and 276L, however, consumed two and three times, respectively, as much as in each of the preceding periods.

The daily ration was given in two equal quantities, the first at 5 30 in the morning and the second at 4 30 in the afternoon. Water was offered one hour after each feeding.

RESULTS

The compositions of the feeds and the data used in calculating the coefficients of digestibility are presented in Tables 7 and 8 in the appendix. Summaries of the results are given in Tables 3, 4, 5, and 6.

In Table 3, the coefficients of digestibility are arranged by periods and by levels of feeding. From this table it will be observed that the plane of nutrition was without effect upon the digestibility. The only statistically significant difference noted was in the case of the coefficients of digestibility of the nitrogen-free extract at the levels of 7 5 and 9 0, respectively. The value at the former level was 61 1 and at the latter, 60 2. The odds that this difference of 0 9 was significant are about 25 : 1.

In regard to the differences between periods, the total digestibility as represented by the values for dry matter and organic matter did not change. Some differences were noted, however, for the individual nutrients. In the case of the nitrogen, the values obtained in period 3 were slightly higher than those obtained in periods 1 and 4. The ether extract values in period 2 were slightly higher than those in period 4. For the crude fibre, the coefficients in period 1 were slightly higher than those in period 3. The reverse of this was true for the nitrogen-free extract.

In Table 4, the data are arranged to bring out any individual differences among the animals. Using the coefficients of digestibility of dry matter and organic matter as criteria, it will be observed that no individual differences were found between animals P24396, P24402 and 276L. The coefficients, however, determined with animal 20023K were between one and two absolute per cent below those determined with the other three animals. This difference was small but significant In regard to the individual nutrients, it was only in the case of the crude fibre values that a significant difference was found between animal 20023K and the other three animals. It would seem, therefore, that while close agreement may be expected between the coefficients of digestibility determined with different, apparently normal, individuals, some slight variations may at

Table 3.—Coefficients of digestibility for periods 1, 2, 3 and 4, arranged by periods and planes of nutrition

Plane of nutrition—(kilos)	4.5	6.0	7.5	9.0	Mean	Coefficient of variation	Standard error of mean
Dry Matter							
Period 1	54.0	57.0	56.9	55.6	55.9	2.51	±0.70
Period 2	56.5	54.7	55.7	54.4	55.3	1.74	±0.48
Period 3	56.2	56.6	54.7	54.7	56.0	1.58	±0.44
Period 4	56.2	56.4	54.9	55.9	55.9	1.20	±0.33
Mean	55.7	56.2	56.0	55.2			
Coefficient of variation	2.08	1.81	1.58	1.30			
Standard error of mean	±0.58	±0.51	±0.44	±0.36			
Organic Matter							
Period 1	55.0	57.8	57.8	56.6	56.8	2.34	±0.66
Period 2	57.7	55.9	56.9	55.4	56.5	1.82	±0.52
Period 3	57.1	57.7	57.4	55.4	56.9	1.81	±0.52
Period 4	57.2	57.1	55.7	56.6	56.7	1.21	±0.34
Mean	56.8	57.1	57.0	56.0			
Coefficient of variation	2.11	1.53	1.60	1.24			
Standard error of mean	±0.60	±0.44	±0.46	±0.35			
Nitrogen							
Period 1	53.1	56.0	52.5	52.4	53.5	3.17	±0.85
Period 2	57.6	55.8	56.2	53.3	55.7	3.22	±0.90
Period 3	58.7	56.8	58.6	57.2	57.8	1.68	±0.48
Period 4	53.1	55.6	51.9	54.9	53.9	3.13	±0.84
Mean	55.6	56.1	54.8	54.5			
Coefficient of variation	5.31	0.94	5.78	3.86			
Standard error of mean	±1.47	±0.26	±1.58	±1.05			
Ether Extract							
Period 1	37.4	41.0	41.3	39.6	39.8	4.47	±0.89
Period 2	39.8	42.2	40.6	39.8	40.6	2.79	±0.57
Period 3	39.3	42.6	40.1	40.9	40.7	3.47	±0.71
Period 4	40.0	38.9	35.9	36.1	37.7	5.42	±1.02
Mean	39.1	41.2	39.5	39.1			
Coefficient of variation	3.04	4.03	6.16	5.32			
Standard error of mean	±0.59	±0.83	±1.22	±1.04			
Crude Fibre							
Period 1	52.3	56.2	56.6	54.7	55.0	3.54	±0.97
Period 2	53.9	51.4	52.9	50.6	52.2	2.84	±0.74
Period 3	52.5	52.4	52.2	49.6	51.7	2.69	±0.70
Period 4	53.3	53.7	51.3	53.7	53.0	2.17	±0.58
Mean	53.0	53.4	53.3	52.2			
Coefficient of variation	1.40	3.89	4.37	4.67			
Standard error of mean	±0.37	±1.04	±1.16	±1.22			
N-Free Extract							
Period 1	58.4	60.3	60.5	59.7	59.7	1.59	±0.47
Period 2	61.3	60.2	61.0	60.4	60.7	0.85	±0.26
Period 3	60.9	62.7	61.9	60.3	61.5	1.73	±0.53
Period 4	61.9	61.3	60.9	60.4	61.1	1.04	±0.32
Mean	60.6	61.1	61.1	60.2			
Coefficient of variation	2.54	1.90	0.97	0.56			
Standard error of mean	±0.77	±0.58	±0.30	±0.17			

TABLE 4.—COEFFICIENTS OF DIGESTIBILITY FOR PERIODS 1 TO 4, ARRANGED BY ANIMALS

	Animal 20023K	Animal P24396	Animal P24402	Animal 276L
Dry Matter				
4.5 kilos	54.0	56.5	56.2	56.2
6.0 kilos	54.7	57.0	56.6	56.4
7.5 kilos	54.9	56.5	56.9	55.7
9.0 kilos	54.7	55.9	54.4	55.6
Mean	54.6	56.5	56.0	56.0
Coefficient of variation	0.73	0.80	2.00	0.69
Standard error of mean	±0.20	±0.23	±0.56	±0.19
Organic Matter				
4.5 kilos	55.0	57.7	57.2	57.1
6.0 kilos	55.9	57.8	57.7	57.1
7.5 kilos	55.7	57.4	57.8	56.9
9.0 kilos	55.4	56.6	55.4	56.6
Mean	55.5	57.4	57.0	56.9
Coefficient of variation	0.71	0.95	1.96	0.42
Standard error of mean	±0.20	±0.27	±0.56	±0.12
Nitrogen				
4.5 kilos	53.1	57.6	53.1	58.7
6.0 kilos	55.8	56.0	56.8	55.6
7.5 kilos	51.9	58.6	52.5	56.2
9.0 kilos	57.2	54.9	53.3	52.4
Mean	54.5	56.8	53.9	55.7
Coefficient of variation	4.46	2.90	3.61	4.65
Standard error of mean	±1.22	±0.82	±0.97	±1.30
Ether Extract				
4.5 kilos	37.4	39.8	40.0	39.3
6.0 kilos	42.2	41.0	42.6	38.9
7.5 kilos	35.9	40.1	41.3	40.6
9.0 kilos	40.9	36.1	39.8	39.6
Mean	39.1	39.3	40.9	39.6
Coefficient of variation	7.52	5.50	3.18	1.83
Standard error of mean	±1.47	±1.08	±0.65	±0.36
Crude Fibre				
4.5 kilos	52.3	53.9	53.3	52.5
6.0 kilos	51.4	56.2	52.4	53.7
7.5 kilos	51.3	52.2	56.6	52.9
9.0 kilos	49.6	53.7	50.6	54.7
Mean	51.2	54.0	53.2	53.5
Coefficient of variation	2.20	3.06	4.73	1.82
Standard error of mean	±0.56	±0.83	±1.26	±0.49
N-Free Extract				
4.5 kilos	58.4	61.3	61.9	60.9
6.0 kilos	60.2	60.3	62.7	61.3
7.5 kilos	60.9	61.9	60.5	61.0
9.0 kilos	60.3	60.4	60.4	59.7
Mean	60.0	61.0	61.4	60.7
Coefficient of variation	1.80	1.25	1.82	1.16
Standard error of mean	±0.54	±0.38	±0.56	±0.35

times occur. These variations would appear, from the data reported above, to be reflected in variations in the fermentation of the crude fibre. This is in accord with previous statements by the authors (*13*) concerning the important role played by the action of fermentation in modifying the apparent digestibility of feeds by ruminants.

TABLE 5.—AVERAGES OF COEFFICIENTS OF DIGESTIBILITY OBTAINED IN PERIODS 1 TO 4

Nutrient	Mean (16 samples)	Range of individual values	Coefficient of variation	Standard error of mean
Dry matter	55.8	54.0–57.0	1.70	±0.24
Organic matter	56.7	55.0–57.8	1.67	±0.24
Nitrogen	55.2	51.9–58.7	4.10	±0.57
Ether extract	39.7	35.9–42.6	4.82	±0.48
Crude fibre	53.0	49.6–56.6	3.53	±0.47
N free extract	60.8	58.4–62.7	1.64	±0.25

Table 5 presents a summary of the sixteen coefficients of digestibility obtained for each nutrient at the levels of 4.5 to 9.0 kilos.

TABLE 6.—COEFFICIENTS OF DIGESTIBILITY FOR PERIOD 5, AT A LEVEL OF 2.5 KILOS PER DAY

Animal No.	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
20023K	52.5	53.2	51.6	37.8	50.7	56.4
P24396	53.9	54.9	51.4	38.6	50.4	59.9
P24402	52.4	53.7	49.9	39.0	49.3	58.4
276L	55.9	57.0	54.5	38.7	55.1	60.0
Mean	53.7	54.7	51.9	38.5	51.4	58.7
Coefficient of variation	3.04	3.09	3.70	1.33	4.97	2.87
Standard error of mean	±0.82	±0.85	±0.96	±0.26	±1.28	±0.84

In Table 6 is given a summary of the coefficients of digestibility obtained in period 5 at the 2.5 level. The results obtained with animal 276L were similar in degree to those obtained at the other levels. In the case of the other three animals, however, the values were slightly lower, so that the averages of the four animals were slightly lower than those of any other level. The differences between the average values given for the levels of 4.5 to 9.0 in Table 5, and the average values for the level of 2.5 were significant. Considering the individual planes of nutrition, though, the differences between the levels of 2.5, 4.5 and 9.0 were not significant, whereas between the 2.5 level and either the 6.0 or 7.5 levels, the differences were, in general, significant. It may be concluded that at the 2.5 level, the digestibility was possibly slightly lowered.

At this latter level, the animals were on a semi-starvation ration. The food was bolted with extreme rapidity and it is possible that rumination and digestion were neither normal nor complete. Even under these conditions, the coefficients were only slightly lowered.

It may, therefore, be justifiably concluded from all the evidence presented above that the plane of nutrition, per se, did not affect the digestibility of a dried roughage when fed to steers.

SUMMARY AND CONCLUSIONS

1. Four grade shorthorn steers were fed a ration of mixed clover and grass hay at levels of 2 5, 4 5, 6 0, 7.5 and 9.0 kilogrammes per animal per day.

2. For the range of 4 5 to 9 0 kilogrammes per day, the plane of nutrition did not significantly affect the coefficients of digestibility.

3. At the 2 5 level, the average values for the coefficients of digestibility were slightly lower than at the other levels. It was suggested that this might be due to the low state of nutrition to which the animals were reduced rather than to an effect of the plane of nutrition, per se.

4. From the data obtained at the levels of 4 5 to 9 0, it was concluded that the digestibility of the hay remained constant from period to period throughout the trial. In certain cases, however, the individual constituents showed slight variations.

5. From the same data it was found that while the digestibilities of all four animals were similar, the values obtained with one animal were slightly but significantly lower than those obtained with the other three. This difference was between one and two absolute per cent.

LITERATURE CITED

1 Armsby, H. P and J A Fries. The available energy of timothy hay. United States Dept of Agr Bur. of Animal Industry Bull No. 51 1903.

2 ———————. Energy values of red clover hay and maize meal. United States Dept. of Agr. Bur of Animal Industry Bull. No 74. 1905.

3. ———————. The available energy of red clover hay. United States Dept of Agr. Bur of Animal Industry Bull. No 101. 1908

4. ———————. The influence of type and age upon the utilization of feed by cows United States Dept of Agr Bur of Animal Industry Bull. No. 128. 1911

5. ———————. Energy values of hominy feed and maize meal for cattle. Jour. Agr. Res. *10* : 599. 1917

6. ———————. Net energy values of alfalfa hay and starch. Jour. Agr. Res. *15* . 269. 1918.

7. Armsby, H. P., J. A. Fries and W. W Braman The energy values of red clover hay and maize meal. Jour Agr. Res. *7* · 379. 1916

8. Forbes, E. B., J. A. Fries and W. W. Braman Net energy values of alfalfa hay and alfalfa meal. Jour. Agr Res. *31* : 987. 1925.

9. Henneberg, W. Neue Beiträge zur Begrundung einer rationellen Fütterung der Wiederkäuer, Heft 1, Göttingen, page 319 and summary table at end. 1870.

10 Henneberg, W. and Stohmann, F. Beiträge zur Begründung einer rationellen Fütterung der Wiederkäuer, Heft 2, Braunschweig, pages 120 and 327. 1864.

11. Honcamp, F. and Gschwendner, B. Untersuchungen über die Zusammensetzung und Verdaulichkeit einer Futtermittel. : Landw. Jahrb. *40* : 731. 1911

12. Honcamp, F. and Koch, E. Ueber den Einflusz der Grösse einer Futterration auf die Verdaulichkeit derselben. Landw. Vers.-Stat. *96* : 45. 1920.

13. Watson, C. J., Muir, G. W., Davidson, W. M. and Dore, J. I.—Studies on Vim Oat Feed. I. Digestibility of Vim Oat Feed. Sci. Agr. *13* : 382. 1933.

14. Wolff, E., Funke, W. and Kreuzhage, E. Versuche über die Verdauungsmögen verschiedener Schaf-rassen für Erhaltungsfutter und für Mastfutter. Landw. Jahrb. *1* : 533. 1872.

15. Wolff, E., Funke, W., Kreuzhage, E. and Kellner, O. Pferde-Futterungsversuche. Landw. Vers.-Stat. *21* : 19. 1878.

Résumé

ÉTUDE DE DIGESTIBILITÉ SUR LES RUMINANTS. 1. DIGESTIBILITÉ DU FOIN DONNÉ EN DIFFÉRENTES QUANTITÉS. C. J. Watson, G. W. Muir et W. M. Davidson, Ferme expérimentale centrale, Ottawa, Ont.

Quatre bœufs Shorthorn métis recevaient une ration composée d'un mélange de foin de trèfle et de graminées, à raison de 2.5, 4.5, 6.0, 7.5, et 9.0 kilogrammes par tête et par jour. Les coefficients de digestibilité n'ont pas été sensiblement affectés tant que la quantité donnée restait dans les limites de 4.5 à 9 kgs. par jour. Au niveau de 2.5 les valeurs moyennes des coefficients de digestibilité étaient un peu plus faibles qu'aux autres niveaux. On a pensé que ceci pourrait être l'effet du pauvre état de nutrition auquel les animaux étaient réduits plutôt que celui du degré de nutrition par lui-même. Se basant sur les résultats obtenus aux niveaux de 4.5 et 9.0, on a conclu que la digestibilité du foin est restée constante d'une période à l'autre pendant tout l'essai. Dans certains cas cependant les éléments constitutifs présentaient de légères variations. D'après les mêmes données on a constaté que la digestibilité des quatre bœufs était semblable, mais que les valeurs obtenues avec un animal étaient légèrement plus faibles, mais de façon significative, que celles obtenues avec les trois autres. La différence était entre un et deux absolu pour cent.

APPENDIX

TABLE 7.—COMPOSITION OF HAY

	Period 1	Period 2	Period 3	Period 4	Period 5
Moisture	7.15	8.02	7.24	7.23	8.20
Ash	6.82	6.86	7.11	6.93	6.99
Crude protein	9.09	9.63	10.00	9.24	9.62
Ether extract	1.91	2.03	2.18	2.12	2.22
Crude fibre	34.34	32.95	33.20	34.42	32.95
N-free extract	40.69	40.51	40.27	40.06	40.02

TABLE 8.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY
(Collection period of 12 days. Weights in kilogrammes)

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Period 1						
Animal 20023K						
In hay	50 139	46 456	0 786	1 031	18 544	21 973
In feces	23 093	20 915	0 369	0 646	8 849	9.153
Digested	27 046	25 541	0 417	0 385	9 695	12 820
Coefficient	54 0	55 0	53 1	37 4	52 3	58 4
Animal P24396						
In hay	66 852	61 942	1 048	1 375	24 725	29 297
In feces	28 783	26 153	0 461	0 812	10 827	11 613
Digested	38 069	35 789	0 587	0 563	13 898	17 684
Coefficient	57 0	57 8	56 0	41.0	56 2	60 3
Animal P24402						
In hay	83 565	77 427	1 310	1 719	30 906	36 621
In feces	36 047	32 644	0.622	1 010	13 421	14.473
Digested	47.518	44 783	0 688	0 709	17 485	22 148
Coefficient	56 9	57 8	52 5	41 3	56 6	60.5
Animal 276L						
In hay	100 278	92 912	1 571	2 063	37 087	43 945
In feces	44 490	40 355	0 748	1 246	16 807	17 694
Digested	55 788	52 557	0 823	0 817	20 280	26 251
Coefficient	55 6	56 6	52 4	39 6	54.7	59.7
Period 2						
Animal 20023K						
In hay	66 225	61 286	1 109	1 463	23 724	29 167
In feces	29.969	27.024	0 490	0 845	11 547	11 621
Digested	36 256	34 262	0 619	0 618	12 177	17 546
Coefficient	54.7	55.9	55 8	42 2	51 4	60 2
Animal P24396						
In hay	49.669	45 964	0 832	1 096	17.793	21 875
In feces	21.619	19.456	0 353	0.660	8 203	8.454
Digested	28.050	26 508	0 479	0 436	9.590	13.421
Coefficient	56 5	57 7	57 6	39 8	53 9	61 3
Animal P24402						
In hay	96 127	88 956	1 615	2 092	34 418	42 348
In feces	43 860	39.675	0 755	1 260	16.986	16.791
Digested	52.267	49 281	0.860	0.832	17.432	25 557
Coefficient	54 4	55.4	53.3	39.8	50.6	60 4
Animal 276L						
In hay	82 782	76 608	1.386	1 827	29.655	36 459
In feces	36 666	32.988	0.607	1 086	13 965	14.236
Digested	46.116	43 620	0 779	0.741	15 690	22 223
Coefficient	55.7	56.9	56.2	40 6	52 9	61.0

TABLE 8.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Continued*
(Collection period of 12 days. Weights in kilogrammes)

Period 3

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Animal 20023K						
In hay	100 181	92 502	1 728	2.354	35 856	43 493
In feces	45 410	41 258	0 740	1 392	18 078	17 259
Digested	54 771	51 244	0 988	0 962	17.778	26 234
Coefficient	54 7	55 4	57 2	40 9	49 6	60 3
Animal P24396						
In hay	83 484	77 085	1 440	1 962	29 880	36 243
In feces	36 335	32 878	0 596	1 176	14 295	13 793
Digested	47 149	44 207	0 844	0 786	15 585	22 450
Coefficient	56 5	57 4	58 6	40 1	52 2	61 9
Animal P24402						
In hay	66 787	61 668	1 152	1 570	23 904	28 994
In feces	28 953	26 065	0 498	0 902	11 373	10 802
Digested	37 834	35 603	0 654	0 668	12 531	18 192
Coefficient	56 6	57 7	56 8	42 6	52 4	62 7
Animal 276L						
In hay	50 091	46 251	0 864	1 177	17 928	21 746
In feces	21 960	19 863	0 357	0 714	8 514	8 495
Digested	28 131	26 383	0 507	0 463	9 414	13 251
Coefficient	56 2	57 1	58 7	39 3	52 5	60 9

Period 4

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Animal 20023K						
In hay	83 493	77 256	1 331	1 908	30 978	36 054
In feces	37.676	34.232	0 640	1 224	15 088	14 085
Digested	45 817	43 024	0 691	0 684	15 890	21 969
Coefficient	54 9	55 7	51 9	35 9	51 3	60 9
Animal P24396						
In hay	92 682	85 741	1 494	2 116	34 279	40 009
In feces	40 882	37 219	0 673	1 353	15 871	15 851
Digested	51 800	48 522	0 821	0 763	18 408	24 158
Coefficient	55 9	56 6	54 9	36 1	53 7	60 4
Animal P24402						
In hay	50 096	46 354	0.799	1 145	18 587	21 632
In feces	21 952	19 826	0 375	0 687	8 679	8 229
Digested	28 144	26 528	0 424	0 458	9 908	13 403
Coefficient	56 2	57 2	53 1	40 0	53 3	61 9
Animal 276L						
In hay	66 794	61 805	1 065	1 526	24 782	28 843
In feces	29 133	26 487	0 473	0 932	11 473	11.177
Digested	37 661	35 318	0 592	0 594	13 309	17 666
Coefficient	56 4	57.1	55 6	38 9	53 7	61.3

TABLE 8.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Concluded*
(Collection period of 12 days. Weights in kilogrammes)

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			Period 5			
Animal 20023K						
In hay	27 540	25 446	0 461	0 666	9 885	12 006
In feces	13 085	11 901	0 223	0 414	4 876	5 229
Digested	14 455	13 545	0 238	0 252	5 009	6 777
Coefficient	52 5	53 2	51 6	37 8	50 7	56 4
Animal P24396						
In hay	27 540	25 446	0 461	0 666	9 885	12 006
In feces	12 709	11 488	0 224	0 409	4 905	4 811
Digested	14 831	13 958	0 237	0 257	4 980	7 195
Coefficient	53 9	54 9	51 4	38 6	50 4	59 9
Animal P24402						
In hay	27 540	25 446	0 461	0 666	9 885	12 006
In feces	13 112	11 785	0 231	0 406	5 014	4 992
Digested	14 428	13 661	0 230	0 260	4 871	7 014
Coefficient	52 4	53 7	49 9	39 0	49 3	58 4
Animal 276L						
In hay	27 540	25 446	0 461	0 666	9 885	12 006
In feces	12 154	10 936	0 210	0 408	4 438	4 796
Digested	15 386	14 510	0 251	0 258	5 447	7 210
Coefficient	55 9	57 0	54 5	38 7	55 1	60 0

MECHANICAL AIDS TO CROP EXPERIMENTS[1]

By H. J. Kemp[2]

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INTRODUCTION

Accuracy and economy in conducting crop experiments depend greatly on the use of suitable mechanical equipment. Modern methods of conducting field experiments with various kinds of crops include the use of a large series of small plots of various sizes and usually consisting of one or more rows measuring from 3½ feet to 18½ feet long. Rod-row test plots for cereal varieties became more extensively used in the United States and Canada about ten years ago. With the introduction of this system of cereal plot testing, appeared certain difficulties affecting either the seeding, harvesting or threshing of the crop. Replication of small plots was deemed essential to secure the maximum of accuracy, but the extent of replication or the number of varieties to be tested was controlled by the hand labour available. Work done by hand labour often gave poor results, even though the work was carefully done. The loss of such work was costly. Perhaps more costly is the retarded progress of experimental work dealing with major problems through lack of suitable facilities.

Some experiments require a certain kind of work to be carried out as quickly as possible in order to secure good results. For instance, at seeding time it is desirable that all the varieties in a test be sown in a comparatively short space of time so that all varieties will get as nearly as possible an even start, since weather factors may influence the results. The use of suitable equipment helps considerably to make this more certain.

During recent years rod-row plot methods have been extended to variety and cultural tests of fodder crops. The recent introduction of commercial fertilizers in Western Canada has also promoted considerable experimentation involving the use of this method. Some difficulties in seeding were encountered when attempts were made to conduct fodder crop and fertilizer tests in rod-row plots, which necessitated the construction of seeding machines suitable for these purposes. Still more recently there has been a demand for a suitable mechanical method of planting single kernels of small grains at two-inch intervals in order to obtain even stands and thereby permit comparisons of individual plants.

DEVELOPMENT OF PLOT MACHINERY AT SWIFT CURRENT

Rod-row testing of cereal varieties began at the Dominion Experimental Station at Swift Current in 1924. Hand labour was used for the work. Difficulties were encountered with seeding, harvesting and threshing. In 1925 an effort was made to correct the difficulties by resorting to much more careful hand methods. The results were no better than those of the previous year. Germination was very irregular. The growth was very patchy. Harvesting was made difficult because of sawfly damage,

[1] Read at the meeting of the Western Canadian Society of Agronomy held in connection with the World's Grain Exhibition and Conference, Regina, Sask., July 28, 1933.
[2] Acting Superintendent.

and a small threshing machine was required to thresh and clean the grain without causing mixing of varieties. Closer observation indicated that rod-row plot testing could be made more successful if suitable mechanical equipment were made available for the work. In 1926 a small rod-row seeder, rod-row cutter and a nursery thresher were designed and constructed. The machines, though far from perfect, greatly improved the cereal work that year. To further improve these machines, a machine shop was equipped at Swift Current with the necessary tools. The machines were re-designed and a number constructed to supply other Experimental Farms of the Dominion Government as well as other institutions.

SEEDING MACHINES

The first rod-row machine to be constructed at Swift Current was a rod-row seeder. Failures to get good stands in 1924 and 1925 were found to be due to the difficulty of getting the seeds planted at an even depth into moist soil below a surface of two or three inches of dry dust. Opening furrows with small hand plows even for a short period of time before planting the seeds seemed to aggravate the trouble. Moist soil became mixed with dry dust and the furrow would soon become dry after exposure to the sun and winds. Frequently the furrows would become blown full with dry dust if they were left exposed too long. As a result much of the seed could not be planted into moist soil by hand, and invariably in covering the seed the loose free running soil would cover the seed before the moist soil could be made to reach it.

In designing the first rod-row seeder an effort was made not only to ensure a uniform stand, but also to facilitate the work of seeding small plots in as many other ways as possible. Steady improvement has been made to these seeders to the present date, and in addition other types have been constructed to meet the needs of special kinds of work. All have been constructed, however, to perform the following work in one operation:

1. Mark and firm the soil for successive drill rows.

2. Open the seed furrows to an even depth.

3. Deposit a previously weighed amount of seed evenly in moist soil in any length of row up to 18½ feet without having seed left over at the end of the row.

4. When seed is not previously weighed and packeted the machine is designed to sow small grains by calibration with a variation of less than 5% from the desired rate.

5. Cover the seed immediately after planting.

6. Pack the soil over the seed.

Several types of seeders have been constructed some of which have been discarded and others are still in the experimental stage. Those which are to be described here are as follows:

1. Rod-row seeder—9-inch circular hopper type.

2. Rod-row seeder—Endless belt type.

3. Continuous row seeder—Calibrated fluted drum type.

Rod-Row Seeder
Nine-inch Fluted Ring Type

Purpose

This seeder is designed to deliver a definite quantity of seed in a definite length of row, the quantity being determined by the thousand-kernel weight and the percentage germination, to ensure the same number of viable seeds being sown in each per unit length of row. This requires that the seed placed in the hopper be sown evenly and so distributed that all the seed is sown as nearly as possible in the prescribed length of row.

Description

The seeder consists of a round aluminum hopper, nine inches in diameter, in which rotates a fluted seed ring. On the seed ring covering the flutes is a loading ring, which forms a circular "V" shaped recess with the inner sloping sides of the round hopper. The distance around this "V" shaped recess is about 24 inches. The seed is placed in a portion of this circular recess, depending on the length of the row to be sown. The portion of the hopper which is to receive seed is determined by trial by pushing the machine over ground similar to that which is to be sown. When the seeder is thus calibrated metal markers are attached to the loading ring to indicate the portion which is to receive seed for the length of row to be sown. When this preliminary is completed, the machine is set to sow any number of rows of the desired length unless soil conditions change sufficiently to affect materially the traction of the drive wheels.

After the seed is distributed evenly in the loading ring, the loading ring is lifted, allowing the seed to fall into the fluted perimeter of the seed ring below. As the machine is pushed over the ground, the seed ring is caused to rotate by means of a 6-inch bevel crown gear on the underside of the hopper meshing with a bevel pinion gear on a ⅝-inch drive shaft. This drive shaft forms the axle for two 12-inch drive wheels. The seed ring makes one revolution for every six revolutions of the drive wheels. As the seed ring rotates, it delivers the seed to an opening in the bottom of the hopper from where it is conducted by a tube to a

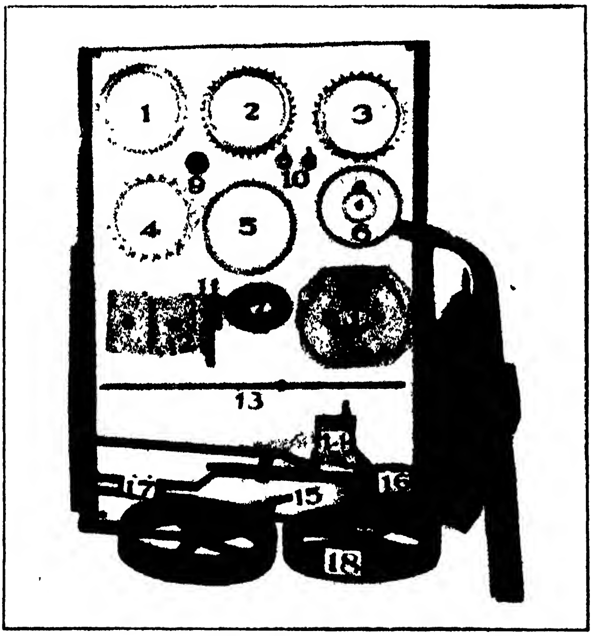

FIGURE 3. Parts of Rod Row Seeder. Nine-inch fluted ring type

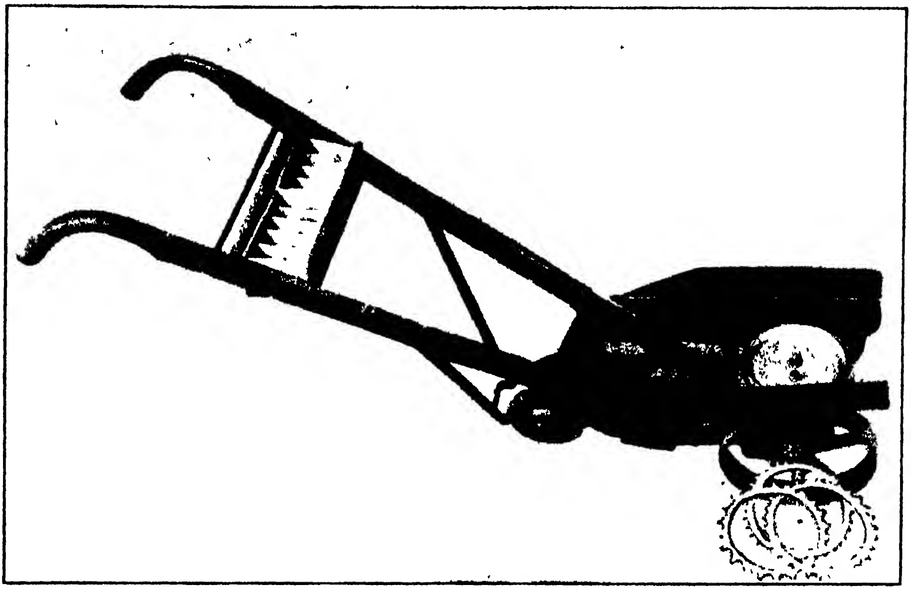

FIGURE 1. Rod Row Seeder. Nine-inch fluted ring type

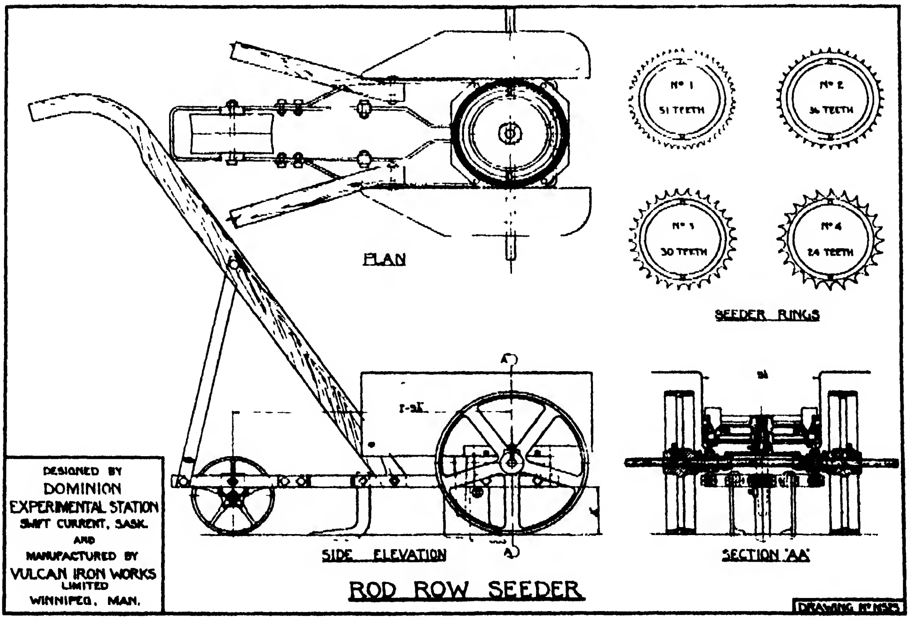

FIGURE 2. Plan of Rod Row Seeder. Nine-inch fluted ring type

furrow opener. The furrow opener is adjustable to sow at various depths to 3 inches deep. The furrow opener is made with sides 4 inches high and extending back 2 inches past the point where seed is delivered to the furrow to keep dry soil from coming into contact with the seed. The seed is thus planted in a fresh moist furrow and immediately covered with soil by the covering irons followed by packing with a 6-inch packing wheel and again packed with one of the drive wheels during the seeding of the next row. The drive wheels are adjustable on the axle shaft so that they can be used as markers and for smoothing and firming the soil previous to planting.

Capacity

The seeder will plant from 300 to 400 single rod rows per 10-hour day depending on soil and weather conditions. The machine is suitable also for sowing many other kinds of seeds besides cereal crops. This machine is now being manufactured by the Vulcan Iron Works, Winnipeg, Manitoba, Canada

Continuous Single-Row Seeder Adjustable Fluted Drum Type

Purpose

The continuous single-row seeder is designed to sow seed at a controlled rate. The rate is based on pounds or bushels per acre and modified by the percentage germination of the seed. Wheat, oats, barley and various grass seeds are sown in any length of row. It is particularly suitable for sowing plots having long rows or a considerable number of short rows. Provision is also made to empty and clean out the hopper readily to facilitate the work when it is necessary to change the seed often.

Description

A quantity of seed is placed in a square shaped hopper constructed of sheet metal. At the bottom of the hopper the seed comes into contact with a revolving 3-inch fluted cylinder or drum. The fluted cylinder is mounted on a threaded drive shaft which is threaded at one end with 12 threads per inch. At the opposite end of this threaded cylinder shaft is a set of 3 spur gears which provides 3 speeds for the fluted cylinder. The spur gears obtain their motion from the two 12-inch drive wheels. Twelve gauge slides, each having different size seed openings varying in width by 1/12-inch are provided. A gauge slide to suit the size and amount of seed to be sown is chosen and placed in position. The fluted seed cylinder is adjusted by screwing it right or left so that the fluted portion ex-

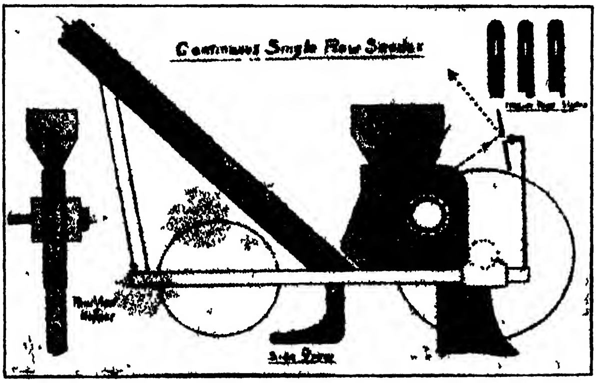

FIGURE 4. Diagram of Continuous Single Row Seeder

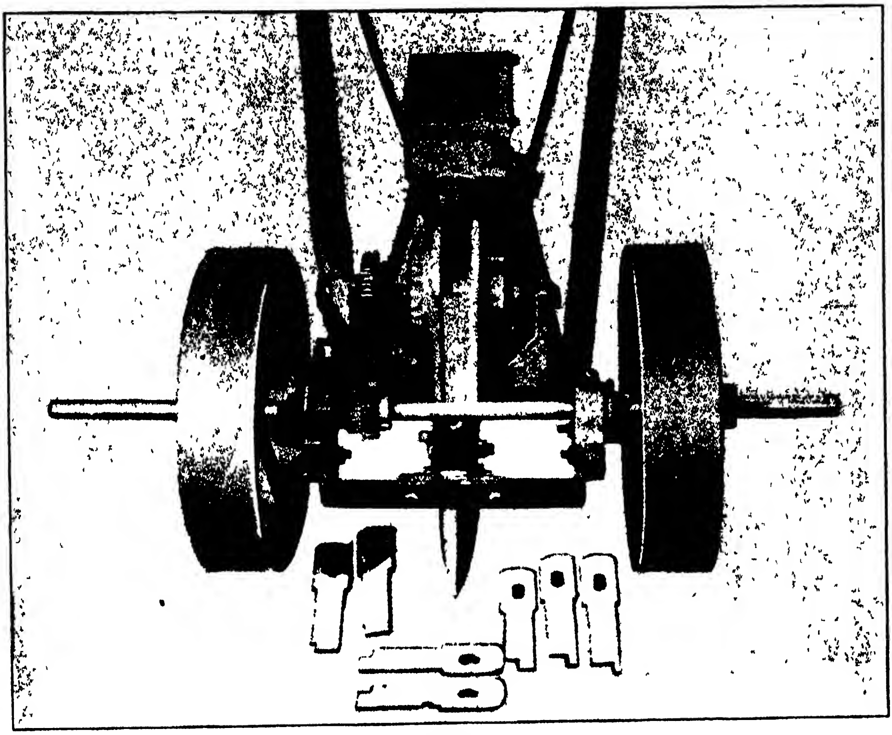

Figure 5. Continuous Single Row Seeder. Front view

posed to the seeds coincides with the width of the opening of the gauge slide. Each complete turn of the fluted cylinder moves it 1/12 of an inch right or left depending on which way it is turned. Thirty-six adjustments within a seed opening space are made possible by the combination of the 3 seed cylinder speeds and the gauge slides. The seed is carried up and over the top of the seed cylinder by the exposed flutes and dropped into a seed conductor tube which guides it to the furrow opener where it is delivered to the soil covered and packed similarly to the seeders previously described.

To determine the proper rate of seeding, the seeder is calibrated for each kind or size of seed by turning the drive wheels to equal the ground travel of a given length of row and the seed thus delivered is weighed to determine the amount. Ten replicated tests with wheat to determine the accuracy of this method of calibrating the seeder indicated a variation of 1/10 of a gram per rod row. This amount of variation would have practically no effect on the resulting yield of the crop as indicated by experiments which will be referred to later.

Capacity

The continuous single-row seeder will plant 1,000 to 1,200 single rod-rows per 10-hour day. This is much faster than the rod-row seeders previously referred to. The greater number of plots seeded is due to the fact that the hopper contains enough seed to sow 100 rod-rows. When the seed is changed, the hopper is readily emptied and is self cleaning so that little time is lost in changing from one variety to another. This seeder,

however, is not suitable for sowing single rod rows or shorter rows. The nine-inch fluted ring type of rod-row seeder is much more suitable for such work.

Rod-Row Seeder
Endless Belt Type

Purpose

This machine was planned especially for testing different kinds of fertilizers and methods of applying it to various field crops. Various weighed quantities representing very light to heavy rates of application may be distributed evenly into moist soil at a specified depth in any length of row up to 22 feet. The machine is self cleaning so that as soon as one row of fertilizer is sown it is ready to receive fertilizer for the next row. The machine also sows seed of various cereals, grasses and legumes.

Description

The distinguishing feature of this machine is the endless rubber belt, 2 inches wide and 36 inches long. The rubber belt is stretched over 2 steel rollers 1 inch in diameter and spaced 20 inches apart centre to centre on an iron frame. A hopper is formed by 2 iron sides of the roller frame, with the top side of the rubber belt forming the bottom of the hopper. Fertilizer or seed is distributed by hand evenly on the endless rubber belt. The portion of the belt to be covered depends on the length of row to be sown, this being determined by trial as with the 9-inch ring type seeder previously described. The endless belt is given motion by a 1-inch roller on the drive wheel axle. The drive wheels are 12 inches in diameter. The ratio of the belt speed to ground travel is 1 foot to 12 feet. As the machine is moved over the ground the fertilizer or seed is carried by the belt to a conductor tube at the front end of the machine when it is guided to the furrow opener and thence to the soil. It is then covered and packed as previously described for the 9-inch fluted ring seeder.

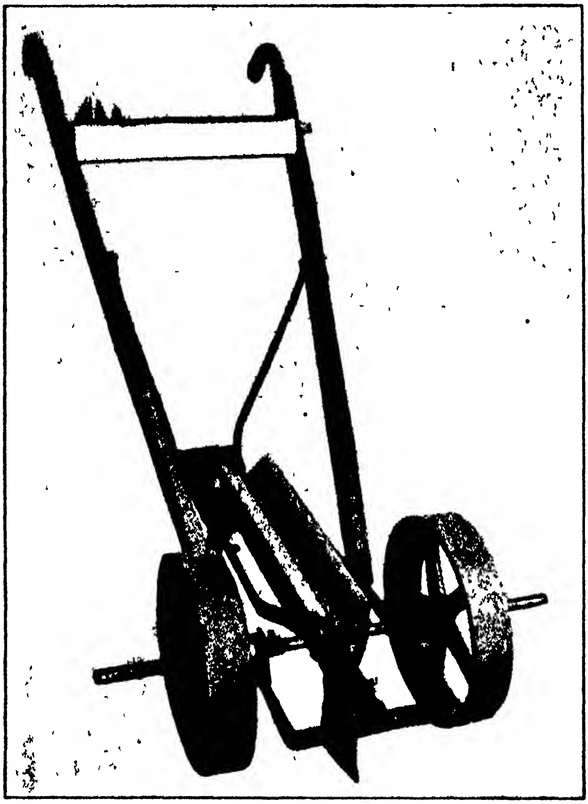

FIGURE 6. Endless Belt Seeder.

Capacity

The endless belt seeder will plant from

300 to 400 single rod rows per 10-hour day depending on soil and weather conditions.

Seeding by Weight vs. Numbers of Viable Kernels

The usual method of seeding grain is to sow by weight or measure expressed in terms of pounds or bushels per acre, as sown by the ordinary grain drill. Some experimenters consider it advisable to sow as nearly as possible an equal number of viable seeds in each row or plot when testing varieties in order that the test may be as uniform as possible in this respect, since seeds may vary greatly in size and viability. This is known as the Swedish method. In actual practice the seed is generally weighed, the weight per rod row being calculated on the basis of the 1,000 kernel weight and the percentage germination. It differs mainly from the ordinary method of seeding, namely by rate, by the consideration of the 1,000 kernel weight, as the viability of the seed is nearly always considered whatever method is adopted to determine the rate to sow.

Kiesselbach and many other experimenters have conducted experiments which indicate that the rate of seeding of a given variety can vary considerably without materially affecting the resulting yield. An experiment conducted at the Swift Current Experimental Station during the past five years shows that the rates of seeding of wheat, oats and barley can vary very widely with little influence on yield when weeds do not compete seriously. For instance, single kernels of wheat spaced ¾ inch, 1 inch, 1¼ inch and 1½ inches apart gave average yields for a period of five years of 23·5, 22·9, 22·6 and 22·3 bushels per acre respectively. In other words, four rates of seeding varying approximately from one bushel to two bushels per acre gave yields from 23·5 bushels to 22 3 bushels per acre. Expressed in other terms we may say that rates of seeding varied as much as 100%, influenced the yield only to the extent of 5.1%. It is quite apparent that cereal crops are able to adjust themselves to widely varying conditions. Examination of data of rates of seeding experiment

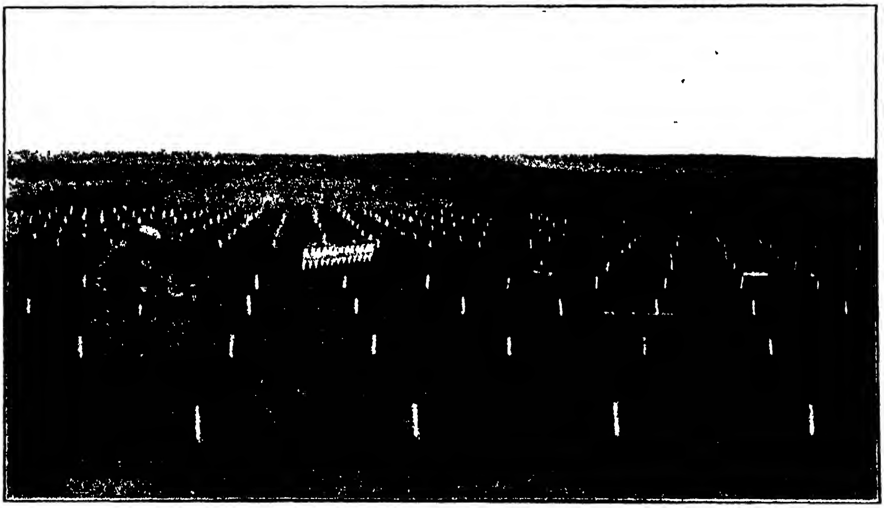

FIGURE 7. Seeding increase plots 3½ ft. × 3 ft. with the Rod Row Seeder.

conducted at the Swift Current Experimental Station in 1926 showed clearly that the grain crops were able to compensate for heavy or light rates of seeding by producing longer or shorter culms, few or many stools, longer or shorter heads with kernels also varying in size and number.

While experiments indicate that rates of seeding varying considerably have little influence on the resulting yield in the absence of competition by

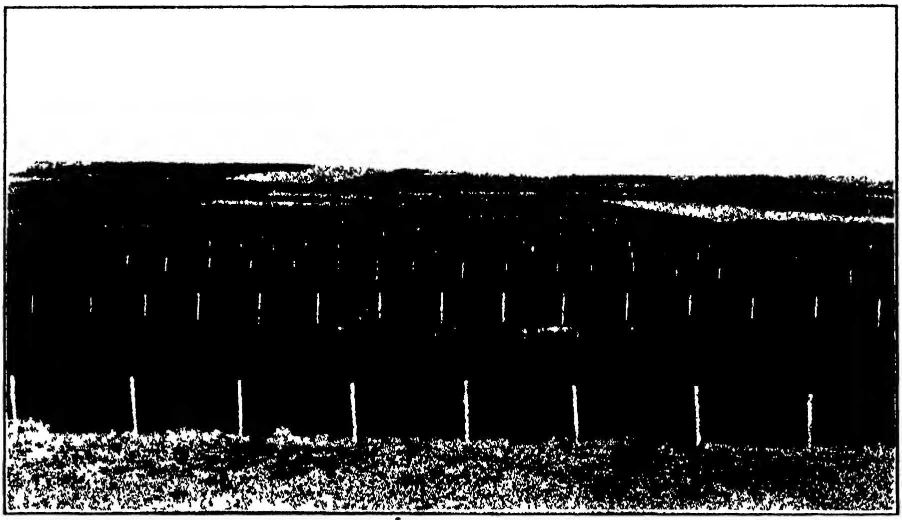

FIGURE 8. Rod Row Plot of Cereal Varieties sown with Rod Row Seeder.

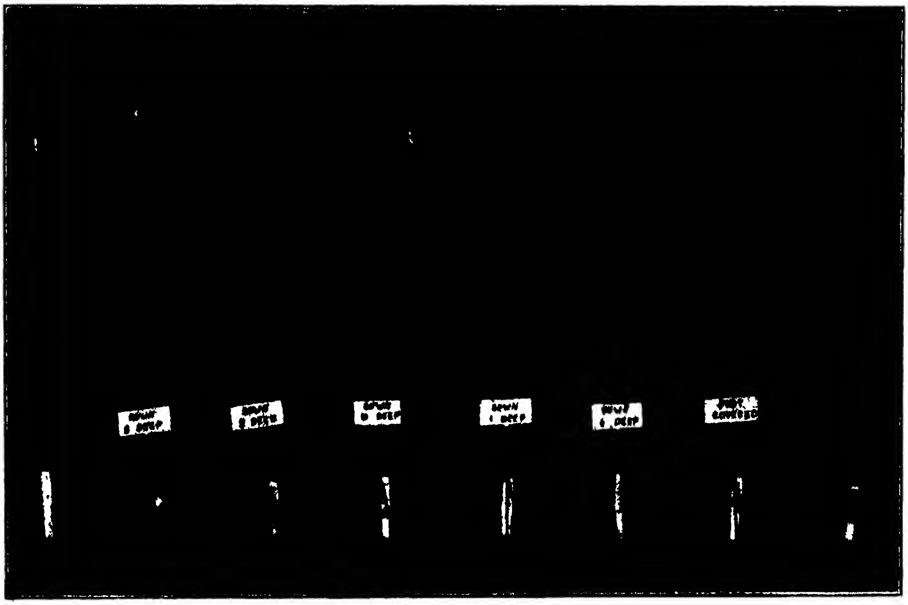

FIGURE 9. Depth of Sowing Brome Grass Experiment. Seeds sown at various depths with rod row seeder.

weeds, the yield data, though perhaps the most important consideration in a variety test, may not be the only important consideration in some experiments. Heavy or light seeding may affect time of maturity, susceptibility to such diseases as rust, length of straw, or the size and quality of the kernels. These are problems that require further experimental study. They are mentioned here since the method chosen for seeding plots may determine to some extent the type of seeder most suitable for the purpose.

Hand Seeding vs. Machine Seeding

Two important factors that are usually considered when determining the merits of hand seeding and machine seeding are: (1) The time required to seed a given number of rows; and (2) the quality of the work Experiments have been conducted at the Swift Current Experimental Station to determine these points Two types of seeders were compared with hand seeding The machines used were the continuous row seeder of the fluted drum type and the rod-row seeder of the 9-inch fluted ring type. Hand seeding was aided by opening a furrow with a small hand plow, then distributing the seeds in the furrow by hand and covering with the plow or a hand rake Wheat, oats and barley were used for the test The time required for seeding by the various methods is as follows.

Method of seeding	Minutes per 36 rod rows	Rod rows per hour
Continuous row seeder	17	128 0
Single rod row seeder	42½	49.6
Hand seeding	73	29 6

The continuous seeder was the fastest method of seeding by a considerable margin. However, the number of plots sown by this machine would average less per hour at the end of a ten-hour day if the replicates were randomized, since considerable time would be required for locating the randomized plots and also for changing seed. A more conservative estimate for sowing randomized plots with the continuous row seeder would be about 90 to 100 rows per hour.

The quality of the work by each method is indicated by the germination of the seed and the percentage stand of crop at harvest time. In the test conducted in 1929 the seed was sown on May 20. Fifty per cent of the seed sown by both the machines germinated, producing plants that reached above ground on May 27. Two days later these same plots obtained their maximum stand. The first seedlings of the hand-seeded plots did not show above the ground until June 20. The average percentage stand of the crops sown by the different methods as they appeared at harvest are indicated in the following table:

Method of seeding	Percentage stand at harvest, average of twelve rod rows		
	Wheat	Oats	Barley
Continuous row seeder	90	85	75
Single rod row seeder	95	95	90
Hand seeding	35	45	75

While the continuous row seeder offers the quickest method of sowing rod row plots, the stands of barley and

oats are not as uniform as those obtained with the single rod row seeder of the 9-inch fluted ring type. This is due to the fact that the seeds of oats and barley vary considerably in size and shape, and the shape of oats, particularly, does not lend itself to automatic feed mechanism that can be calibrated very closely. The difficulty is minimized by sowing heavier rates. As a rule a seeder that is designed to sow oats satisfactorily will sow wheat and barley with little or no difficulty.

The single rod row seeder of the 9-inch fluted ring type has proven itself at Swift Current to be the most useful kind of seeder for nursery work because of its versatility. It may be used for seeding a wide range of seeds of different sizes and shapes in rows of any length up to 22 feet. It is adaptable for any of the seeding methods as space seeding, seeding by numbers of viable kernels, seeding by weight, or seeding by volume. The seed may be distributed to the hopper from packets or by a measure from a bulk lot. The packeting of seed before seeding effects systematic and efficient methods of seeding when used with the single rod row seeder.

Hand seeding has consistently proven to be a very slow and unsatisfactory method, particularly in dry seasons when poor germination and stands usually result in the loss of a season's work

FIGURE 10. Nursery Seeding Experiment. Hand seeding versus sowing with Rod Row Seeder and Continuous Row Seeder. Hand sown seed germinated very poorly.

HARVESTING

Extensive series of rod-row plots create a great amount of slow tedious work in harvesting when it is done by means of a sickle or a similar tool. In order to do this work more quickly, more conveniently, and to reduce the cost of labour several rod-row harvesting machines have been designed and constructed at Swift Current. Some were powered by a light weight

gas engine; others were pushed by hand. Those which were driven by engine power were too cumbersome and heavy, though the cutting mechanism was satisfactory. The cutting device was simply a 12-inch length of a hay mower knife. The addition of a gas engine also complicated the machine unnecessarily, as well as adding considerable to its weight and cost. Theoretically, the energy that can be supplied continuously by one man is sufficient to powerize a cutting device if it is properly applied. In 1931 it was observed that ordinary hedge shears with weighted handles would cut a single row of grain. The weighted handles were simply 3½ foot lengths of ¾-inch iron pipe. The handles were sufficiently heavy so that when one was allowed to fall by its own weight it supplied sufficient power to operate the shear to which it was attached and cut standing grain. This hedge shear type of cutter did not seem to lend itself very readily to the cutting of rod row plots mainly due to its mode of operation which made the work of cutting both awkward and slow. These difficulties may be eventually overcome. Because of the simplicity of the hedge shears further efforts are being made to make this form of cutter adaptable to rod row harvesting.

Rotary Shear Rod Row Cutter

Purpose

The rod-row harvester which is now in use at Swift Current is of the rotary shear type. It was designed to overcome the difficulties of the hedge shear type as already mentioned The rotary shear affords a continuous cutting action and overcomes the slow spasmodic shearing action of the hedge shears. It is operated entirely by man power. This harvester is most suited to short and medium crops. Very rank growth may require some modification in design to cut the crop. The rotary shear however seems to be the most logical kind of cutting mechanism on which to base a suitable design.

Description

The rotary shear cutter consists of two flat disc-shaped steel knives three inches in diameter. The revolving knives are mounted on vertical spindles spaced so that the knives overlap about ¾ of an inch of their perimeter. The knives are also adjustable vertically on the spindle. The revolving knives are rotated through a set of mitre gears located in a specially shaped aluminium casting which forms also a sealed housing for gears, bearings and light transmission lubricant. The front part of the casting is made to form a "V" shaped opening into which the rows of grain are guided to be cut by the rotary shears. The entire machine is actuated by the ground wheels through a chain and sprocket drive which supplies power to the mitre gears and rotates the knives. A sheet metal basket is set between the handles to contain the cut grain. As the machine is pushed along the ground the rotary knives shear off the standing grain about three inches above the ground and the cut grain falls back into the metal receiving box between the handles.

Capacity

Two men using the machine can cut 1,500 rows per day. One man is required to push the cutter while the other guides the rows of grain by hand towards the hopper. This is not always necessary when the grain

is standing erect. When the row is cut, one man lifts the cut grain from the receiving box and holds it while the second man ties the bundle and labels it. The labels are prepared before harvest time.

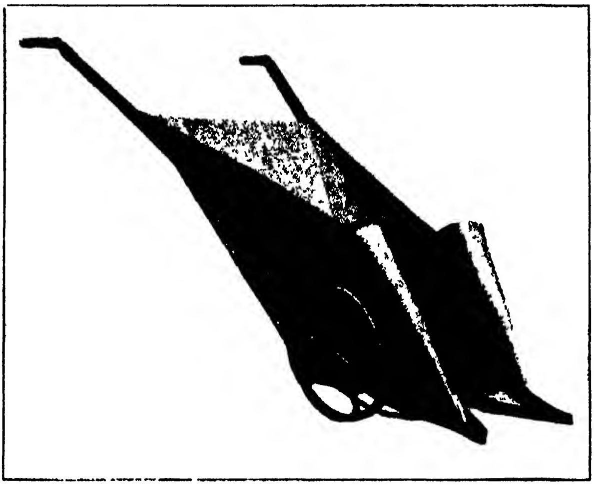

FIGURE 11. Rotary Shear Rod Row Cutter. Front view

FIGURE 12. Rotary Shear Rod Row Cutter View of underside (11).

THRESHING

Rod Row Thresher

Purpose

As with seeding and harvesting, a large number of small plots entails a great deal of work in threshing. To do this work a small thresher of simple design constructed so as to avoid lodging of grain and consequent mixing is an important requisite. Such a machine should thresh, clean and deliver the grain ready for weighing and also be self cleaning after each lot is threshed. The machine here described has been designed with these aims in view.

Description

The rod row thresher is of all-metal construction with the exception of the pitman arm and some bearing support blocks which are made of hardwood. Special castings are used in the construction of the machine. The thresher without the feed table is 7 feet long, $2\frac{1}{2}$ feet wide and $5\frac{1}{2}$ feet high. The frame construction of the machine consists of $1\frac{1}{4} \times \frac{3}{16}$-inch angle steel re-inforced with $\frac{1}{8}$-inch steel gusset plates. The feed table and cylinder are located at the top and at one end of the steel frame.

The cylinder housing is formed by specially designed iron castings. A heavy flat face cast iron pulley fitted with teeth is used for the threshing cylinder. The size of the pulley is 10 inches in diameter, 10-inch face, $1\frac{7}{16}$-inch bore, and fitted with two set screws. The face of the pulley is drilled and tapped to receive eight rows of teeth. The teeth are made from $\frac{1}{2} \times \frac{1}{2}$ square cold rolled steel threaded at one end with a $\frac{3}{8}$-inch standard thread. The teeth are screwed into the tapped holes on the face of the pulley and secured on the underside of the pulley face with a lock washer and nut. The teeth are spaced 1 19/64-inches apart on centres so that the space between the cylinder and concave teeth is almost $\frac{5}{32}$ of an inch. After the teeth have been screwed into the cylinder, the cylinder is placed in a lathe to true up the sides and ends of any teeth that may be slightly out of alignment. The cylinder is then balanced while it is between the lathe centres. Four rows of $\frac{3}{4}$-inch concave teeth are screwed into a semicircular cast iron concave plate. The spacing of the teeth is similar to that of the cylinder teeth except that the rows are closer together being $2\frac{13}{16}$ inches apart. The concave plate forms also the top part of the cylinder housing. The concave teeth are thus inverted, and being located in this position above the cylinder, prevent grain and straw from lodging in the concave teeth and save the necessity of frequently cleaning out. In order to prevent grain getting inside the cylinder, the sides of the cylinder are recessed into the sides of the cylinder housing $\frac{1}{8}$ of an inch with a clearance of $\frac{1}{32}$ inch. A $1\frac{7}{16}$ cylinder shaft is turned down at the ends to $1\frac{3}{16}$ inch diameter to fit the ball bearing located in the hub projections on the side of the cylinder housing.

The threshed grain and straw pass from the cylinder down into an oscillating chute. This chute is made of galvanized iron with seams half way up the sides to provide a smooth bottom free from crevices. One end of the bottom of the chute is formed of 22 metal louvres. Fourteen of the louvres nearest to the cylinder are spaced to provide openings $\frac{1}{2}$ inch wide. These separate the threshed grain from the straw. The remaining eight louvres are spaced to provide openings $\frac{7}{8}$ inch wide. These allow

unthreshed heads and grain that may escape from the first set of louvres to be trapped into a tailing box below. The remaining straw passes out of the end of the chute. The louvres form the only screening mechanism for separating the grain from the straw. Their design affords considerable strength, but is also plain and simple, and made so expressly for the purpose of reducing to a minimum the opportunity of straw or heads to lodge, so that cleaning out at this part of the machine is seldom required. The separation of the grain from the straw and chaff is aided by a controlled blast of air supplied by a 3½-inch forge blower located at the cylinder end of the machine. The air is directed through a pipe 24 inches long to within 30 inches of the louvres. The distance between the end of the pipe and the louvres allows the blast of air to spread before it strikes the lips of the louvres. The lips of the louvres deflect the air currents into the chute so that the straw and chaff are carried out at the end of the chute. The threshed grain which falls through the half inch louvres drops into a funnel shaped receptacle below which guides it into a sloping 4-inch pipe. Here the grain is recleansed by a controlled blast of air supplied by a 2½-inch pressure blower the outlet of which is connected with the sloping 4-inch pipe. The air blast is directed upward against the descending grain and the chaff is carried over to the tailings box.

Operation

In operating the thresher, the cylinder is driven at a speed of about 1,000 r.p.m. The pitman eccentric shaft rotates 200 r.p.m. to oscillate the conveyer chute. Both the pressure blowers are given a speed of 2,000 r.p.m.

The actual operation of threshing the grain consists of feeding small sheaves evenly to the cylinder after the bands and labels are removed. All the straw is allowed to go through the machine. The threshed grain and straw pass from the cylinder to the conveyer chute. Threshed grain falls through the first set of louvres and drops down into the recleaner on its way to the receiving pan at the bottom of the machine. Unthreshed heads then passed through a second set of louvres are caught in the tailings box and handed back to the cylinder to be re-threshed or through the back end of the chute to be recleaned. The remaining straw and chaff is delivered out at the end of the conveyer chute.

Three men are required to operate the machine to full capacity. One feeds the machine, the second returns the tailings to the feeder and empties the grain receiving pan after each lot is threshed. The third man weighs the samples and records the weights and other data such as the weight per measured bushel.

Peas and beans may be threshed by belting the machine so that the cylinder runs in an opposite direction at about 200 r.p.m., to avoid contact with the concave teeth, but the conveyor chute and the fans must be belted to run at their normal speed and the fans in the proper direction. Running the cylinder backwards at a slow speed avoids cracking the seeds.

This machine is now manufactured by the Vulcan Iron Works, Winnipeg, Manitoba, Canada.

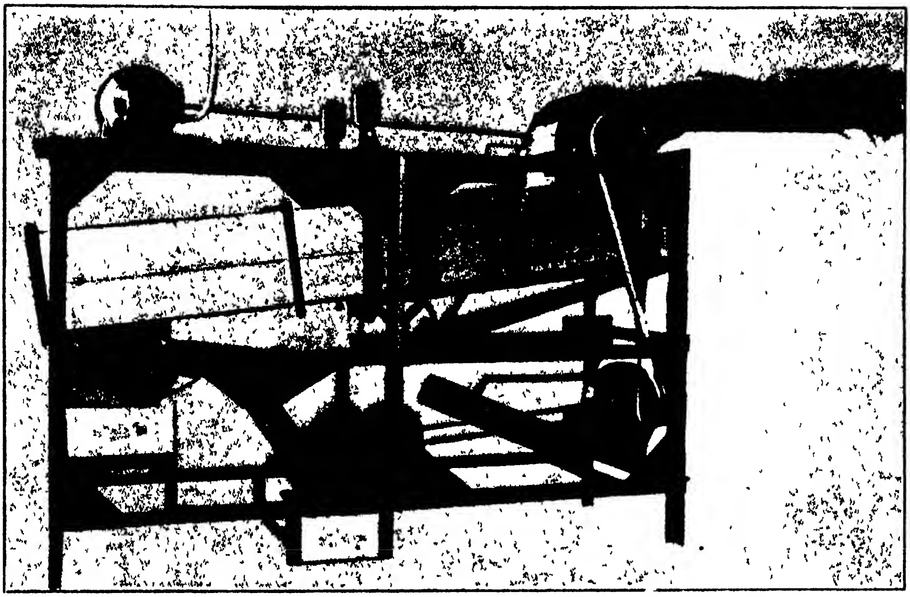

FIGURE 13. Cereal Nursery Thresher for Rod Row Plots and small lots of grain

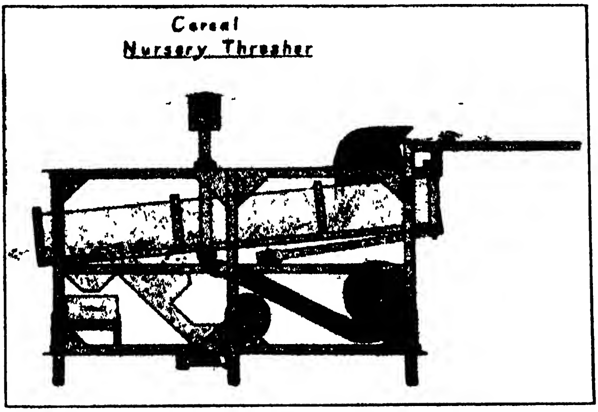

FIGURE 14. Diagram of Cereal Nursery Thresher.

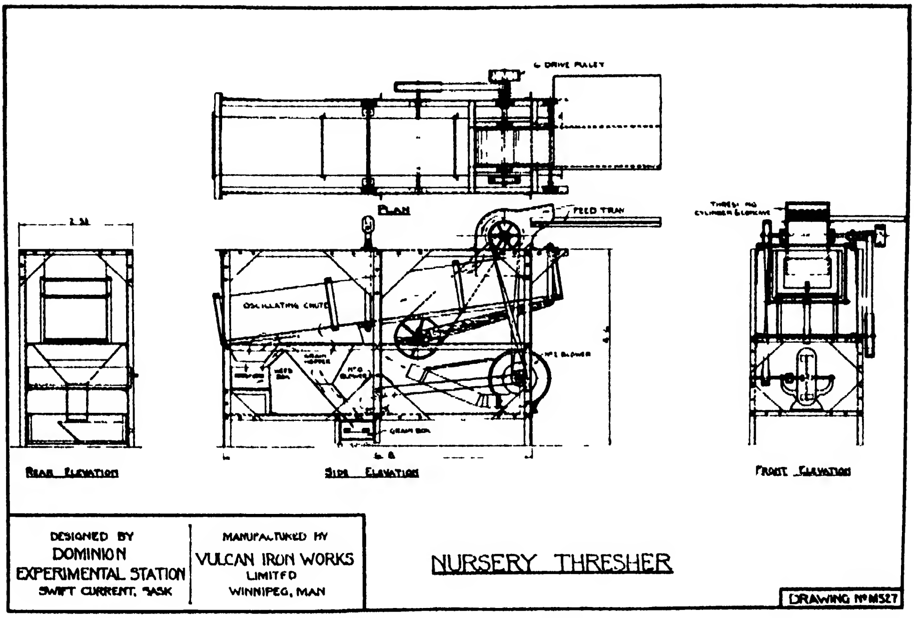

FIGURE 15. Assembly Plan of Cereal Nursery Thresher

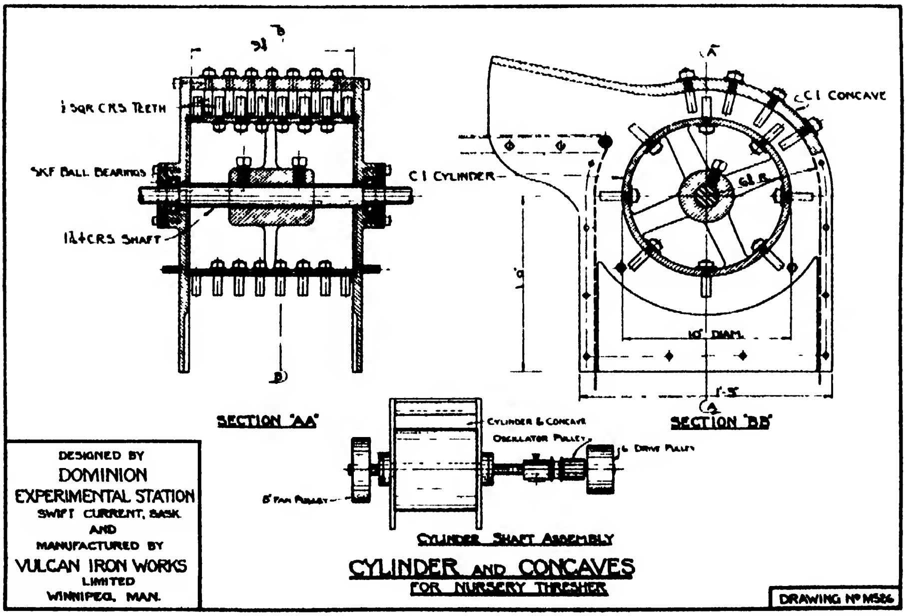

FIGURE 16. Plan of Cylinder and Housing of Cereal Nursery Thresher.

Head Thresher

Purpose

Single heads or the product of short rows as head rows are threshed with this machine. The machine is self-cleaning so that a large number of single heads or small lots can be threshed and cleaned in rapid succession without the necessity of cleaning out between each sample.

Description

The machine is about 30 inches high and mounted on a wood base 30 inches long and 14 inches wide. On the top part of the thresher is a funnel shaped entrance into which heads of grain are introduced for threshing. Directly below the feed chute is the cylinder housing which encloses a solid steel cylinder 4 inches in diameter and 4 inches long. The cylinder is recessed into the sides of the cylinder housing to prevent lodging of grain or chaff. Six rows of teeth made from $\frac{3}{8}$-inch square cold rolled steel are screwed into the cylinder. Three rows of teeth are used for the concave. The concave teeth are screwed into the top part of the cylinder housing so that the teeth are inverted forming what is sometimes called an "overshot" cylinder. As with the rod-row thresher the inverted concave teeth are used to prevent lodging and consequent mixing of seeds. The cylinder is carried on a $\frac{5}{8}$-inch steel shaft which rotates on two ball bearings. These are the only bearings in the machine. The cylinder shaft also carries two 6-bladed fans, one on each side of the cylinder housing. The fans are enclosed. The air blast created by these fans is the only means provided for cleaning the grain. The cylinder and fans operate at speeds from 5,000 to 7,000 r.p.m. Below the cylinder is a 4 inch × 4 inch vertical

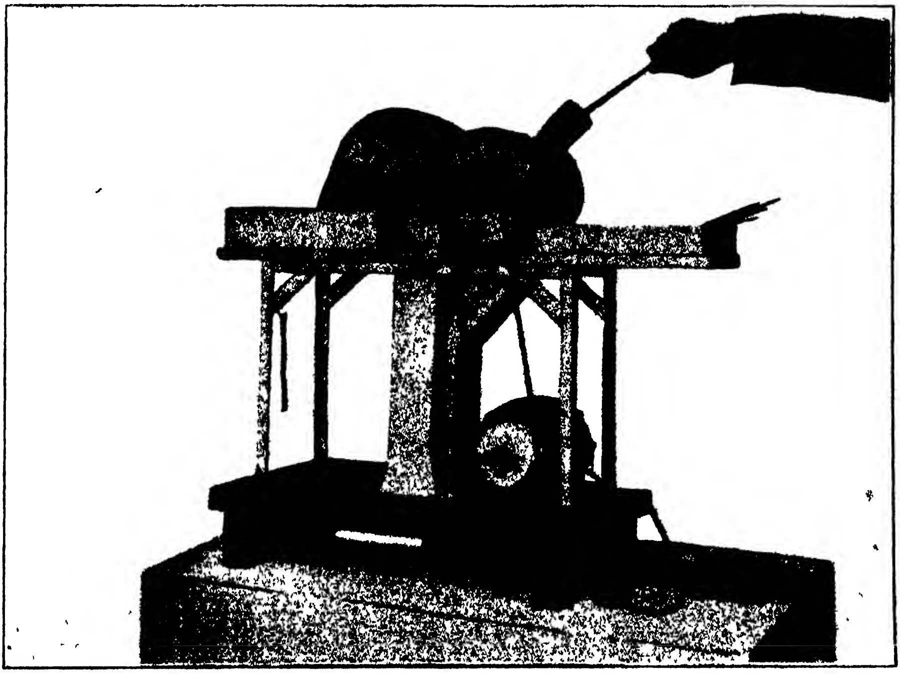

FIGURE 17. Head Row Thresher.

metal chute about 20 inches long which conveys the threshed grain and chaff toward the specially shaped grain pan at the bottom of the chute. The chute also forms the recleaning chamber. On each side of the 4 inch × 4 inch chute is a smaller chute which conducts the air blast from the fans to the grain receiving pan. The bottom of the grain pan is rounded to deflect the air upwards through the 4 inch × 4 inch square chute where it meets the threshed grain and chaff. The chaff is carried upward by the air blast and out of the machine at the top and into a screened receptacle. The grain continues to fall through the rising air currents to the receiving pan below. The two sources of air from the fans on each side of the machine together with the specially shaped grain pan is essential to overcome dead air pockets.

Operation

The heads are pushed through the funnel shaped chute to the revolving cylinder so that just the heads are threshed and the straw withdrawn. The heads are best handled when they have about 8 or 10 inches of straw, since the head can be held in the cylinder for a few seconds to secure good threshing. The threshed grain and chaff drop down the vertical chute where they are separated by the air blast. The threshed grain which falls into the grain pan is then put into suitable containers. Two men are required to operate the machine to full capacity. One man feeds the heads into the machine while the other receives the threshed grain and places it in numbered containers. Two men can thus thresh 200 heads per hour if the envelopes or other containers are previously numbered or otherwise prepared.

GERMINATION OF RUSSIAN PIGWEED SEEDS IN ICE AND ON FROZEN SOIL[1]

O. S. Aamodt[2]

University of Alberta, Edmonton, Alberta

[Received for publication January 12, 1935]

Numerous studies have been made on the most suitable temperatures for the germination of seeds in seed testing laboratories. Little information exists on the subject of minimum temperatures for seed germination of our commonly grown crop plants and the weeds with which they must compete.

Some investigators have found in laboratory tests that the seeds of several of our crop plants, especially clovers and cereals, will germinate at or near freezing temperatures. Under field conditions germination of seeds does not proceed, as a rule, at such low temperatures owing to the brief duration of the favourable temperature and the extremes to which the temperature may fall at night. Unless the seedlings possessed natural resistance to freezing, they would probably fail to survive the low night temperatures.

In a study (*1*) on the effect of low temperatures on the survival of several cereal crop varieties and wild oats, observations were made in the field on their abilities to survive low temperatures under natural conditions. On March 16th, in the spring of 1934, before there was any indication of growth in either spring or winter cereal crops, the writer found seeds of Russian pigweed (*Axyris amaranthoides* L.) germinating and seedlings growing in pure ice and frozen soil (see Figure 1).

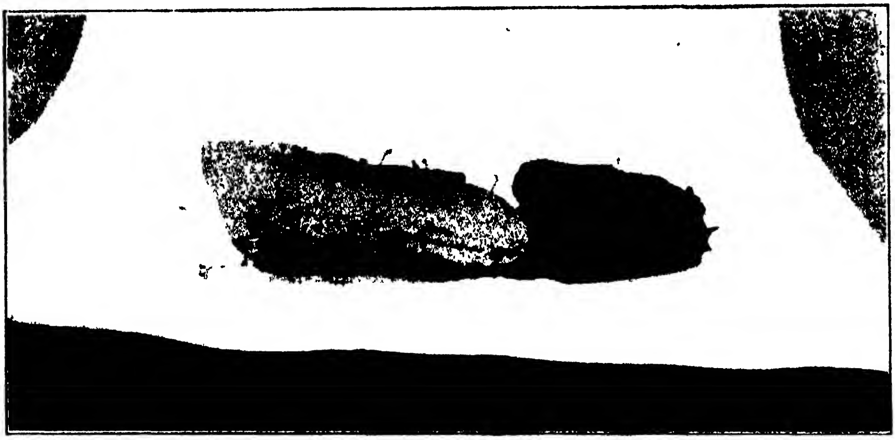

Figure 1. Russian Pigweed germinating in ice and on frozen soil. University of Alberta, Edmonton. March 16, 1934.

Mature plants, from the previous year's growth, containing numerous seeds were still standing erect. A portion of the ground underneath the plants was covered with heavy ice. Numerous Russian pigweed seeds had fallen from the dry plants to the ice and the frozen soil. The small black

[1] Contribution from the Department of Field Crops, University of Alberta, Edmonton, Canada.
[2] Professor of Genetics and Plant Breeding.

seeds that fell on the clear ice appeared to have absorbed heat from the sun's rays and to have melted their way into the ice. The heat liberated in respiration of the seed may also have been a factor, especially after germination had begun. These seeds were found at depths in the ice varying from one-eighth to one inch. In each case the path that the seed had travelled through the ice was evident from the cylindrical hole slightly larger than the diameter of the seed, and extending from the seed to the surface of the ice. In many instances the seeds had germinated in the bottoms of these cavities and the seedlings had elongated sufficiently to emerge above the surface of the ice as shown on the left in Figure 1.

The surface of the soil not covered with ice thawed out to a depth of approximately one-eighth of an inch during the day. Russian pigweed seeds falling on this surface appeared to have germinated readily as shown on the right in Figure 1. Those seedlings that started in the ice continued normal growth as soon as the ice melted and they made a contact with the soil beneath.

The climatic conditions prior to the development of the Russian pigweed seedlings may be of interest. The maximum and minimum air temperatures and the precipitation for the fifteen days previous to the time of the observation were as shown in Table 1.

There was bright clear sunshine most of the day time for the first half of March when it was not snowing or raining. Most of the snow fell during the night and melted during the day. On several occasions the night temperatures fell considerably below freezing, and on March 9th as low as 5° F. below zero. In spite of these extreme conditions the seedlings survived and produced strong healthy plants.

TABLE 1

Date	Temperature in degrees F.		Precipitation in inches	
	Maximum	Minimum	Snow	Rain
March 1	45	32	---	Trace
2	48	33	—	—
3	42	26	—	—
4	30	24	- -	- -
5	20	11	—	—
6	23	10	1 50	—
7	27	3	25	—
8	16	5	10	-
9	47	− 5	- -	—
10	60	5		-
11	62	35	—	—
12	40	40	—	—
13	42	19	—	—
14	48	26	—	Trace
15	25	24	1 25	---
16	18	6	.25	—

In some of the short season areas, and in years in which there is a late spring, field crops, especially cereals, are often sown without a previous cultivation of the soil. Weed seeds that are able to germinate at low temperatures, and that will survive freezing temperatures during germination and in the seedling stages, have a great advantage in becoming established before the crop is sown. Definite and more extensive information on the minimum temperatures at which seeds of our crop plants and common weeds germinate would be of great value.

REFERENCE

1. AAMODT, O. S. and PLATT, A. W. Resistance of wild oats and some common cereal varieties to freezing temperatures. Sci. Agric. *14* : 645-650. 1934.

THE ECONOMIC ANNALIST

A REVIEW OF AGRICULTURAL BUSINESS PREPARED QUARTERLY BY THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA

Vol. V, No. 1. March, 1935

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

Wholesale prices in Canada showed a gain of four and one-half points in 1934 compared with 1933. The increase in farm products was about eight points, being almost evenly divided between field products and animal products. In the month of January, wholesale prices in general advanced slightly. On the other hand the index or prices of farm products was a little lower. Recession in field products more than offset a small gain in prices of live stock products. It will be noted that retail prices advanced about one point in 1934 and the index stood at 78.9 in January, 1935.

Employment.—The increase in employment as at February 1 was less than normal. The index, therefore, receded to 99 9, compared with 101.2 as at January 1. It should be noted, however, that the seasonal recession at the beginning of January was less than normal and, therefore, an increase at the first of February of less than normal proportions is not considered to be a serious matter. Employment was more active at February 1, 1934, in all economic areas except the Maritime Provinces.

Physical Volume of Business.—The physical volume of business showed a substantial gain in January, the index rising to 96.5. Industrial production advanced from 91.0 in December to 96 3 in January. Mineral production and manufacturing were lower. Iron and steel production displayed considerable activity. Construction showed a substantial gain, contracts awarded rising from 31.5 to 92.8. Building permits were lower and cost of construction rose slightly. The total index was 71 3 compared with 31.2 in December. Electric power production increased. Agricultural marketings continued to decline, the index of grain marketings being 19.3. Live stock marketings on the other hand advanced from 67 3 to 81.5, an increase in shipments of cattle, calves, and sheep being responsible for the gain. The index of cold storage holdings rose from 135.7 to 143 7.

Provisional averages for the physical volume of business in 1934 show a substantial increase in business activity in 1934 compared with 1933. The total index was 94.2 during the past year while in 1933 it was 79.7. In fact the annual average index in 1934 was higher than in any year since 1929. The same was true of the index of industrial production. Agricultural marketings were much below those of 1933, however, the index dropping from 105.1 to 88.5. The index of grain marketings was 90.2, while that of live stock was 80.5. Cold storage holdings on the whole showed little change compared with 1933.

Wages of Farm Help.—The average monthly wage paid for male help during the summer season of 1934 is reported by the Agricultural Branch of the Dominion Bureau of Statistics to have been $18 compared with $17 in 1933, $19 in 1932 and $25 in 1931. The value of board supplied was estimated at $15 per month, 1934 to 1932, and at $18 in 1931. The estimated total of wages and board was, therefore, $33 during the past year, $32 in 1931, $34 in 1932 and $43 in 1931.

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1934	71.6	59.0	53.9	67.6	78.9	94.2	93.6	88.5	114.2
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.8
Nov.	71.2	61.2	55.7	70.4	79.4	96.5	97.0	51.2	130.4
Dec.	71.2	61.6	56.0	70.9	79.0	92.4	91.0	36.0	135.7
1935									
Jan.	71.5	61.4	55.7	71.0	78.9	96.5	96.3	30.6	143.7

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1932, p. 15.

2. Wholesale prices of Canadian products of farm origin only See Prices and Price Indexes 1913-1932, p. 32, and Monthly Mimeographs 1933 and 1934.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries, See Prices and price Indexes 1913-1928, pp 181-185, 290-293. 1926=100.

Prices and Price Indexes 1913-1931, p. 122, and Monthly Mimeographs 1933-1934.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

In 1934 the monthly wage of men employed on farms was highest in British Columbia where it averaged $43 and was lowest in Prince Edward Island and Quebec in which privinces the average wage was $30 per month.

Wages of men employed by the year averaged $171 in 1934, compared with $161 in 1933, $176 in 1932, and $240 in 1931. Allowances for board were $167, $161, $165, $199 respectively in the four years for which this comparison has been made. Thus the combined value of wages and board was $338 in 1934, $322 in 1933, $341 in 1932, and $439 in 1931. The total cost of year help in 1934 was, therefore, just about $100 less than in 1931.

ACTS OF INCORPORATION OF CO-OPERATIVE ASSOCIATIONS IN CANADA

A. E. RICHARDS[1]

One of the main objects of a co-operative association is to effect savings in the marketing of farm products or the purchasing of supplies. Its membership is usually confined to those who patronize the association. Other distinctive features are a limitation on the ownership of shares of capital stock, one vote per member, a moderate rate of return on capital within definite limits, and the disposition of any surplus, after reserves have been provided for, in proportion to patronage. By enacting statutory laws governing the establishment of co-operative associations governments have given recognition to the usefulness of this type of organization in the economic life of the community.

Records received by the Economics Branch from farmers' business organizations throughout Canada show that out of 809 associations reporting, 757 or 94% are incorporated. While a number of companies have received their charters by special acts, the great majority are incorporated under provincial co-operative associations acts. This large percentage of incorporated co-operative associations, which includes 2,000 local branches and represents over 3,000 places of business, is to be commended as it shows business foresight and a realization of the responsibilities of business enterprise on the part of co-operative leaders and officials.

The co-operative associations acts establish the legal status of an organization, determine its powers and limitations, and chart a general course of procedure to which an association incorporated under such acts must conform.

The application to organize a co-operative which is usually termed a memorandum of association must be signed by a responsible group of persons who are initiating the organization and deposited in the office of the Provincial Secretary, Registrar of Companies or Registrar of Co-operative Associations. The memorandum must state the name of the proposed association, designate the place of business, the objects of the association, the amount and kinds of capital stock and the value of shares.

The by-laws which must comply with the act are the common rules applying to a particular company which are adopted by the membership. These rules govern membership relations. Such matters as the bonding of officers and employees handling funds of the association, the setting of the fiscal year, provision for dividends if any, and provision for amendments are contained in the by-laws. For trading associations the inclusion of a clause dealing with the policy of the association in regard to cash sales or limitations upon credit is important.

If the memorandum and rules appear to the Registrar to comply with the act, he issues a certificate showing that the association is incorporated and a copy of this certificate with a statement of the objects of the association are published, for a stated period of time in the provincial Gazette. This certificate of incorporation is evidence that the requirements of the act in respect to incorporation have been complied with, and that the association is duly incorporated and authorized to carry on business.

Incorporation provides a number of safeguards to business enterprises which are made legal by statutory law. It creates a corporation separate and distinct from the membership which composes the association. It establishes the principle of limited liability. Thus, if the incorporated company by some misfortune falls into heavy debt, suit for the recovery of the debt must be brought against the company and not against the individual members which compose it except for the amount remaining unpaid on their membership fees or subscriptions for shares. Limited liability obtained through incorporation facilitates the raising of capital. Other desirable and protective features of incorporation are that real estate and other property may be owned and transferred in the name of the company and the property interest of its members is made definite and more easily transferable.

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[1] Agricultural Economist, Economics Branch, Department of Agriculture, Ottawa.

ESSENTIAL FEATURES OF PROVINCIAL CO-OPERATIVE ASSOCIATIONS ACTS

	British Columbia Co-operative Associations Act R.S.B.C. 1924	Alberta Co-operative Marketing Associations Act 1924	Alberta Co-operative Associations Act R.S.A. 1922
1. Formation	Five or more persons. Name must include word "Co-operative." Must not include word "Company or "Limited.	Ten or more persons. May be formed with or without capital.	Ten or more persons. Shall include word "Limited."
2. Capital	Unlimited. Number of shares of such denomination as may be fixed by the memorandum.	Common and preference shares provided for. Memorandum must state number and value.	Unlimited. Memorandum must state number and denomination.
3. Stock-holding privileges	Member may hold any number subject to provisions of rules. Must be paid for in cash. No share to be issued at a discount.	Limited per shareholder to one-twentieth of total number of ordinary shares.	Regulated by by-law
4. Redemption of shares	May redeem and re-issue its own shares.	May redeem shares provided debts do not exceed 50% of assets.	May re-purchase shares.
5. Limitation of dividend	8%.	8% on ordinary and preference shares.	No provision.
6. Dividend to non-member patron.	Yes.	No provision.	No provision.
7. Patronage refund.	Yes.	Yes.	No provision.
8. Borrowing powers	May borrow and raise money and may issue debentures for same.	May borrow money and issue bonds and debentures.	May raise money by mortgage and other assurances.
9. Eligibility for membership	Open to anyone who complies with rules of the association.	Limited to persons engaged in agricultural production. Tenant or landlord receiving share of crop as rental.	Open to anyone who complies with the rules of association and purchases a share.
10. Liability of members	Individually limited to amount unpaid on shares.	Individually limited to amount unpaid on membership fee or share subscription.	Individually limited to amount unpaid on shares.
11. Loans to members	May advance money to members on security of real and personal property.	Yes.	Yes. On security of real or personal property.
12. Voting	One member, one vote. Voting by proxy allowed, subject to rules.	One member, one vote. Proxy and mail voting allowed, subject to rules.	One vote per member by ballot.
13. Marketing contract	Yes.	Yes, term limited to 7 years.	
14. Breach of contract	Liquidated damages may be fixed and association entitled to injunction privileges and to an order for specific performance. Penalty for procuring breach.	No provision	
15. Apportionment of surplus	Not less than 10% to be placed in reserve fund until fund reaches 30% of paid-up capital or as provided in the Act.	To proper reserves.	To any lawful purpose.
16. Auditors	Appointed by association.	Auditor appointed must be approved by Minister.	Two or more persons appointed as the rules provide
17. Annual Report	Must be filed with Registrar.	Must be filed with Registrar and available to members.	Must be filed with Registrar and available to members.
18. Registration fee	$10.00.	$5.00.	$5.00.

	Saskatchewan Co-operative Marketing Associations Act R.S.S. 1930	Saskatchewan Co-operative Associations Act R.S.S 1930	Manitoba Co-operative Corporations Act 1932
1. Formation	Ten or more persons. Words "Co-operative" "Marketing," "Association," "Limited," must form part of name.	Five or more persons. "Co-operative Association Limited" shall be the last three words of name.	Seven or more persons. Word "Co-operative" must be included in name and "Limited" if company has share capital.
2. Capital	Unlimited. Memorandum must state amount of share capital and denomination of each share	As set forth in memorandum	Preference and ordinary shares provided for.
3. Stock-holding privileges	Governed by by-laws. Shares can only be held by members.	No restriction, governed by rules.	Limited per shareholder to one-twentieth of total number of ordinary shares.
4. Redemption of shares	May redeem shares provided debts do not exceed 50% of assets.	May redeem all but one share per member.	May redeem shares provided debts do not exceed 50% of assets.
5. Limitation of dividend	8%.	6%, subject to by-law.	7%.
6. Dividend to non-member patron	No provision	Yes. Credited on account of capital stock.	Credited on account of capital stock or membership fee.
7. Patronage refund	Yes.	Yes. Remainder of surplus distributed in proportion to volume of business.	Yes Remainder to be divided among members in proportion to volume of business.
8. Borrowing powers	May borrow money and issue bonds and debentures.	In accordance with Companies Act.	In accordance with Companies Act.
9. Eligibility for membership	Limited to persons engaged in agricultural production. Tenant or landlord receiving share of crops as rental	Open to anyone who complies with rules of the association.	Shall be producers of commodity proposed to be marketed in marketing association.
10. Liability of members	Individually limited to amount unpaid on membership fee or share subscription or promissory note	Limited to amount unpaid on shares. Lien on members share permitted for collection of debt.	Individually limited to amount unpaid on share subscription or membership fee.
11. Loans to members	May advance money to members on agreed terms.	In accordance with Companies Act.	No provision.
12. Voting	One member, one vote. May vote by mail No proxy voting allowed.	One member, one vote. No proxy voting allowed	One member, one vote. No voting by proxy except in case of Branch representatives.
13. Marketing contract	Yes, term limited to 7 years.		Yes
14. Breach of contract	Liquidated damages may be collected. Penalty for inducing breach of contract $50.00 to $200.00.		Entitled to injunction and specific performance.
15. Apportionment of surplus	To proper reserves.	10% to be placed in reserve until fund equals 30% of paid-up capital stock.	10% to be placed in reserve until fund equals 30% of paid-up capital stock.
16. Auditors	Submit accounts for audit by chartered accountant	Accounts must be audited.	Regulated by memorandum of agreement.
17. Annual Report	Must be made to Registrar and available to members.	Must be made to Registrar and available to members.	Must be filed with Provincial Secretary.
18. Registration fee	$10 00.	$1 00.	$12 50 up.

	Ontario Co-operative Corporations Act R.S.O. 1927	Quebec Co-operative Agricultural Associations Act R.S. 1922	Nova Scotia Fruit Produce and Warehouse Assn's. Act R.S.N.S. 1923
1. Formation	Five or more persons. Word 'Co-operative must be part of name	Twenty-five or more persons known as "shareholder-producers Affiliated producers pay $2.00 annual fee. Cannot attend general meetings or vote	Five or more persons. "Limited must be included as last word in name.
2. Capital	May be in form of share capital or capital notes from members, payable on demand.	Preference and ordinary shares Amount of each $10.00 Holders of preferred shares cannot attend or vote at general meetings	Not less than $1,000.00 of which one-half shall be subscribed Capital stock increased by two-thirds vote
3. Stock-holding privileges	No restriction.	Maximum holding per member—ten shares. Minimum holding—five shares	No limitation, governed by rules
4 Redemption of shares	No provision	Preferred shares only redeemable	No provision
5. Limitation of dividend	8% per annum	7% limit on preferred shares.	No limitation, governed by rules.
6. Dividend to non-member patron		No provision	No provision
7 Patronage refund	Yes In proportion to volume of business To non-members at such proportionate rate as determined by by laws		
8 Borrowing powers	In accordance with Companies Act	Limited to an amount equal to four times aggregate amount of subscribed shares and reserve fund	May borrow, execute mortgages and issue debentures, and pledge debentures as security for loans.
9. Eligibility for membership	No restriction	Must be producers	No restriction.
10. Liability of members	Limited to amount of unpaid portion of capital note or share	Limited to amount of holding.	Limited to amount unpaid on shares.
11. Loans to members	Prohibited by Companies Act	No provision	No provision
12. Voting	One member, one vote No proxy voting except in case of Branch representatives	One vote per member No proxy voting	One vote for each share held.
13. Marketing contract	No provision	Provided for in by-laws	Has power to regulate sale of members product.
14 Breach of contract	No provision		Penalties can be collected
15 Apportionment of surplus	Up to 20% may be set aside annually in reserve and 5% in educational fund	To proper reserves and remainder credited to shareholder-producers on account on preferred shares.	May be placed in reserve fund.
16. Auditors	Appointed by association.	Accounts must be audited by an auditor	Governed by by-laws.
17 Annual Report	Must be filed with Provincial Secretary	Copy must be sent to Minister of Agriculture	As provided in by-laws.
18. Registration fee	Subject to Order-in-Council		No fee.

As the result of incorporation, serious responsibilities devolve upon the directors as trustees of the shareholders. They should inform themselves on the responsibilities which they assume. On the part of the shareholders or members, due discretion should be exercised to assure the election of capable men to act as directors.

It is impossible in a brief review to discuss separately the co-operative associations acts of the provinces. They are set out in the foregoing pages under headings for comparison. It will be noted that certain underlying principles are common to all although the definition of powers is much more explicit and their application permits a larger scope of activity under the acts of certain provinces than of others

Since all of the acts are designed to serve the same purpose, greater uniformity of provisions and wording of clauses should clarify interprovincial relations and would facilitate any Dominion-wide undertaking of a co-operative character. In the Maritime Provinces, acts have been framed to suit certain commodity groups and do not permit of general application. The Co-operative Union of Canada which represents a large body of consumer co-operative activity and opinion and representative co-operative marketing groups in the Dominion have given consideration to this problem and have urged the implementing of Dominion legislation.

In certain provinces the existing acts do not meet the needs of consumer co-operatives to the same extent as marketing associations and may account in some degree for the lack of progress in this type of co-operative activity. Records in the Economics Branch show that at the present time, in terms of places of business and total membership, marketing organizations outnumber purchasing associations of farmers by 10 to 1. In the matter of volume of business, marketing associations transact twenty times the business handled by purchasing agencies. Membership in the co-operative marketing associations which reported to the Economics Branch numbered 318,597 persons as compared with 30,546 members in purchasing organizations. The total annual business amounted to $138,025,004 for the marketing companies compared with $7,278,950 for the purchasing group

In view of the steady growth of co-operative activity in Canada, consideration may be given to a number of features generally regarded as fundamental in a co-operative act These are listed below without discussion.

1. Membership to be confined to or composed largely of producers or persons who expect to patronize the association.

2. The sale of capital stock should be confined to producers or persons who expect to contribute to the business of the association unless it is necessary to finance by public subscription in which case stock sold to persons other than users of the services of the association should be of non-voting type.

3. Voting power and control of the organization must be retained by those who use the services of the organization.

4. Some limitation on the amount of stock which a person may own.

5. A limitation of the rate of dividends on stock.

6. Provision for crediting patronage refunds to non-members and members as payments on new or additional stock.

7. Transfer of shares subject to the approval of directors.

8. Limitation of voting to "one-man, one-vote" or some other manner of voting which gives substantially this effect. (Voting on basis of business done during preceding fiscal years is worthy of consideration.

9. Limitation of individual liability for debts of the association.

10. Provision for the use of a contract if desired by members.

11. Statement of method by which dissolution may be effected.

12. Provisions that after all expenses are provided for out of gross income, the balance for distribution may be apportioned among the following:—

(*a*) An adequate reserve.

(*b*) Interest on invested capital.

(c) An educational fund (optional).

(d) Balance distributed among eligible patrons of the association in proportion to volume of business contributed.

13. A limitation on the amount of business which may be done with non-members and non-producers.

14. Outline of duties and responsibilities of directors.

15. A restriction of the use of the term "co-operative" in names of associations.

16. Requirement that an annual return or statement of business, membership, etc., be filed with the registrar of such associations.

17. Provision for audit of books and accounts by a qualified person.

NEW ZEALAND DAIRY INDUSTRY COMMISSION REPORTS

The report of the New Zealand Dairy Industry Commission is of considerable interest to Canadian readers. This Commission was appointed by the Governor General under authoriity of the Dairy Industry Act of 1908 and the Dairy Export Control Act 1923, and was given the task of finding a solution to the crisis which has arisen in the industry by reason of the current high cost of production of butterfat and a reduction in price obtainable overseas for butter and cheese produced in New Zealand. The report submitted to the Governor General on September 30, 1934 reviews in detail the problems confronting the New Zealand dairy industry. Some of the significant facts are given below. Emphasis is placed upon the sensitiveness of the economic structure of New Zealand to external conditions. This arises from the fact that the greater part of the national income must be obtained from the sale of a few kinds of products in export markets.

"The economic problems which confront New Zealand at the present time and which are of particular moment to the dairy industry arise out of the changes in the nature of international trade that have occurred in post-war years. The most notable feature of these changes has been the rapid growth of policies of national self-sufficiency in practically all European countries. Particularly in recent years have restrictive trade practices increased both in scope and intensity, with the result that exporting industries have found it more and more difficult either to hold markets previously established or to penetrate new markets.

The extreme range of variability in cost of production between districts is somewhat over one pence per pound of butterfat with an average cost of 4.093 pence per pound for the 550 farms covered by an investigation conducted by the Department of Agriculture in the main dairy districts of the North Island. The farms selected for study were regarded as being above average in efficiency and were chosen because the owners were able to provide reasonably accurate records of receipts and expenditures. The Commission found that despite low costs of production (exclusive of interest) that the present output which was considered to be far short of the potential supply was at present incapable of being marketed at remunerative prices to the farmer.

"Looking at the situation from the farmers' point of view, we are at once impressed by his achievements in increasing production, and by the fact that his increased output has brought him no gain." Between 1920 and 1934, the average butterfat production per cow increased by approximately 68.7 pounds. Total imports of cheese to the United Kingdom market have been fairly uniform since 1925 approximating 150,000 tons. New Zealand's exports have increased but in view of the fact that total imports have not increased, it is considered probable that the saturation point may be approaching or that it actually has been reached. This is emphasized by the fact that there has been some decrease in the per capita consumption of cheese and until the situation is clarified, it is not considered to be wise to further develop export of cheese.

Increased consumption of butter in Great Britain has been obtained to some extent through a gross increase in fat consumption but mainly at the expense of margerine. Recently, the rate of displacement has been less rapid despite reductions in the price of butter.

Analysis of butter stocks shows that increasing difficulty is being experienced in moving butter rapidly in this market. The estimated stocks of butter in London, including stocks in private and provincial stores and in steamers not discharged as at 1st October were as follows.— 1932—20,000 tons, 1933—26,000 tons, and 1934—37,000 tons. There is no information as to the source of supply of this stored butter, but it is estimated that 40% of the 1934 quantity is of foreign origin, principally from the Baltic States and Russia; 40% is New Zealand butter and the remaining Australian and Irish."

The commission anticipates that the Government of the United Kingdom will impose a limit on imports of dairy produce with or without the levying of differential duties, and will, in fixing quotas within that limit, have regard to the relative claims of Empire and foreign countries. Should quantitative restrictions be placed on the export of dairy products, possibilities of controlling the rate of production may have to be considered. The report states that any subsidy which is virtually a sustenance payment would be viewed with disfavour by the United Kingdom. The risk involved in abandoning at this date our policy of unsubsidized export is too serious to be undertaken on behalf of a proposal which has no outstanding merits of its own."

"It is recommended that control of the industry be entrusted to a new Dairy Produce Control Board. This Board should in addition to its other activities control the local marketing of butter and cheese. Envisaging the necessities of the industry in regard to new markets for surplus produce, and the measures of control of production and marketing likely to become necessary to meet the present and future problems of the industry, as well as control of the local marketing of butter and cheese, to which reference has been made elsewhere in the report, the Commission believes that the State must of necessity appoint some members of the Board The proposal that farm and factory instruction should be the responsibility of the newly constituted Dairy-produce Control Board is an additional reason for the State interest in the appointment of the Board. For these reasons, the Commission has decided to recommend for the Board a constitution which it is considered gives recognition and fair balance to the interests both of the State and the producers.

It is, therefore, recommended that the Dairy-produce Control Board be reconstituted and given wider powers, embracing control of volume and quality of the production, processing, and manufacture of dairy-produce and control of local marketing as well as export marketing."

The Bureau of Agricultural Economics, Washington, D.C., recently released a report on direct marketing of hogs. A press release announcing the report states: "Direct marketing has not lowered the general level of hog prices, nor has it operated to reduce returns to producers. The sharp decline in hog prices in recent years was due to the drastic reduction in consumer income associated with the decline in the general price level, and to reduced foreign demand for American hog products. It has not reduced competition for hogs. There are no fixed price differences between public markets and interior points. A rise or decline in hog prices is as likely to occur first at interior points as at public markets. Direct marketing has not increased marketing costs nor widened the margins between prices of hogs and prices of hog products. Nor has it deprived public markets of supplies of the various qualities of hogs sufficient for registering prices for the different grades. In general, the study shows that direct marketing has not operated to the disadvantage of hog producers. It does point out, however, that direct marketing has substantially reduced the number of hogs received for sale at public markets, which has adversely affected the interests of stockyard operators and market agencies at some public markets."

FARM LABOUR

E. G. GREST[1]

The family size of farm is often referred to as the best size of farm with which to build up a perment agriculture in Western Canada. This particular size of farm is difficult to translate into a definite number of acres of land in any area as the size of family varies considerably from farm to farm and even varies a great deal in size through one generation. The majority of farms in Western Canada approach very closely to a family business; for example, during the year 1930 in five main areas in Alberta and Saskatchewan 82.7% of all the farm labour used on 573 farms was supplied by the farm operator and his family.[2]

Amount and Cost of Labour.—The amount of the different types of hired and family labour used on these farms and the cash value including cash expenditure for board are shown in Table 1. The average cost of board was $7.46 per month. This was included in the total cash value or cost of labour and the cash value of labour per month shown in Table 1. The non-cash cost of living is the amount of farm garden produce, farm supplied meats, milk, eggs, and dwelling accommodation used by the whole labour force. The average cost of man labour for these farms in 1930 was 35.2 cents per hour or $57 per month.

TABLE 1.—COST OF HIRED AND FAMILY LABOUR USED ON 537 FARMS IN SASKATCHEWAN AND ALBERTA DURING THE YEAR ENDING APRIL 1, 1931

	Months of labour		Cash cost of labour		Cash cost per month
	Total	Per farm	Total	Per farm	
Hired labour:					
Year help	490 0	0 91	$20,080	$37	$41
Month help	935 8	1 75	46,389	86	50
Day help	565 5	1 05	50,313	94	89
Total hired labour	1,991 3	3 71	$116,782	$217	$59
Family labour:					
Farm operator	6,184 8	11 52	$324,542	$605	$52
Wife of operator	302 3	0 56	9,631	18	32
Operator's sons	2,680 9	4 99	99,072	184	37
Other unpaid labour	362 7	0 68	14,749	27	41
Total family labour	9,530 7	17 75	$447,994	$834	$47
Total hired and family labour	11,522 0	21 46	$564,776	$1,051	$49
Total non-cash living	—	—	90,017	168	8
Total value of labour	-	-	$654,793	$1,219	$57
Total hours man labour	—	—	1,816,419	3,466	—
Cost per hour in cents	—	—	35 2	—	—
Family labour in per cent of total	82 7	—	79 3	—	—

Since the family supplied slightly over four-fifths of all the farm labour on these farms in 1930 the problem was to find sufficient useful employment for this labour throughout the year. Family labour did not vary greatly with the seasons of the year and in most cases was available for the full 12 months. The farmer usually

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[2] Study conducted in co-operation with the Canadian Pioneer Problems Committee, 1931.

does not pay out a definite cash wage for family labour, but food, clothing and incidentals must be provided and consideration must also be given to the fact that the farmer's son working on his father's farm is investing his time in the farm business and is entitled to a portion of the farm or to financial assistance when starting in business for himself. In view of this fact a charge for family labour is considered a legitimate cost. Moreover, in order to place all farms on a comparable basis, family labour must be charged against the business. A good farm operator will not be more wasteful of family labour than he would be of seasonal hired help but it is very frequently the case that family labour is available in excess of farm needs. Such a situation might be overcome by increasing the size of the farm or by modifying the type of business so as to provide employment for the additional help throughout the year.

Factors Affecting the Cost per Hour of Man Labour.—The importance of obtaining a maximum number of hours of work per man per year is demonstrated in Table 2. There is a very definite decrease in the cost per hour of man labour with an increase of hours worked per year. This is shown by a rate of 47.6 cents per hour for the group working less than 1,500 hours per man per year and a labour cost of 26.3 cents per hour for those working 2,500 hours and over per year.

TABLE 2.—INFLUENCE OF HOURS WORKED PER MAN EQUIVALENT AND TIME SPENT CARING FOR LIVE STOCK ON THE COST OF LABOUR PER HOUR ON 537 FARMS IN SASKATCHEWAN AND ALBERTA 1930-31

Per cent of hours spent caring for live stock	Hours worked per man equivalent									
	Under 1,500		1,500–1,999		2,000–2,499		2,500 and over		All farms	
	Number of farms	Labour rate per hour (cts.)	Number of farms	Labour rate per hour (cts.)	Number of farms	Labour rate per hour (cts.)	Number of farms	Labour rate per hour (cts.)	Number of farms	Labour rate per hour (cts.)
Under 30%	40	58.3	28	41.7	19	38.1	6	26.0	93	43.4
30–39%	20	44.6	42	39.0	38	36.8	26	30.0	126	36.8
40–49%	34	45.3	44	37.5	52	29.8	37	25.7	167	33.1
50% and over	26	39.9	44	35.9	39	28.0	42	24.3	151	30.6
All farms	120	47.6	158	38.3	148	32.6	111	26.3	537	35.2

The data were also sorted according to the percentage of labour spent on caring for live stock as well as according to the percentage of field work accomplished by horses. As the percentage of the total hours spent on choring increased, the cost of man labour per hour decreased and hours worked per man increased. The decrease in labour cost per hour is not entirely due to the increase in hours worked per man but probably one-half could be attributed to this factor. The inclusion of a certain amount of live stock in the farm business assists in making use of family labour throughout the year, and hired labour can be obtained for short periods such as during harvesting when more labour is required than can normally be supplied by the operator and his family.

On farms on which only a portion of the field work is done with horses and the balance with tractors it would be expected that the percentage of time spent in caring for all live stock, including horses, would be less than on farms on which all of the field work is done with horses. This fact is brought out in Table 3. The decrease in time spent caring for live stock must be almost entirely due to the fact that less time was spent in caring for horses, as the returns from live stock and live stock products sold and consumed on the farm per man equivalent is practically the same in each group with the exception of the group of farms in which 99 to 67% of the field work was done by horses. The decrease in hours worked per man with the increased use of the tractor for field work is almost negligible. The use of the tractor is therefore responsible for only a small share of the increase in the rate for man labour.

TABLE 3.—INFLUENCE OF HOURS WORKED PER MAN EQUIVALENT AND PERCENTAGE OF FIELD WORK HANDLED BY HORSES ON THE COST OF LABOUR PER HOUR ON 537 FARMS IN SASKATCHEWAN AND ALBERTA 1930-31

Per cent of field work handled by horses	Hours worked per man equivalent: Under 1,500		1,500–1,999		2,000–2,499		2,500 and over		All farms	
	Number of farms	Labour rate per hour	Number of farms	Labour rate per hour	Number of farms	Labour rate per hour	Number of farms	Labour rate per hour	Number of farms	Labour rate per hour
		(cts)		(cts.)		(cts.)		(cts)		(cts)
100%	68	42 9	82	35 7	77	29 2	69	24 2	296	32 0
99–67%	9	48 6	23	39 5	20	33 0	13	27 3	65	35.6
66–34%	15	47 0	27	39 2	29	34.5	15	27 7	86	36.3
33–0%	28	62 7	26	43 0	22	37 6	14	33 2	90	43.3
All farms	120	47 6	158	38 3	148	32 6	111	26 3	537	35.2

The inclusion of live stock on the tractor-operated farms should give nearly as good a distribution of labour requirements throughout the year as on the horse-operated farms because the live stock kept would require considerable attention during the winter while horses on farms as a rule are running out during the winter and receive little attention. Therefore, the increased cost of labour per hour must be due to the better trained class of labour required on the tractor-operated farms. On account of the higher class of labour used, it naturally follows that a representative sample of farm operators would estimate labour at a higher monthly rate which results in increasing the cost per hour.

TABLE 4.—RELATIONSHIP OF ACRES OF CROPLAND TO PERCENTAGE OF HOURS SPENT CHORING AND HOURS PER MAN EQUIVALENT —537 FARMS IN SASKATCHEWAN AND ALBERTA 1930-31

Per cent of hours spent caring for live stock	Hours per man equivalent	Live stock returns per man equivalent	Per cent hours spent choring	Size of farm (Acres of cropland)
Under 30%	1,725	$160	23.3	622
30–39%	1,949	284	35 2	570
40–49%	1,956	335	44.3	446
50% and over	2,071	451	56 6	306
All farms	1,939	317	41.6	466

From data on labour costs not presented in the tables it was found that the cost of man labour per hour increased more or less regularly as the farms increased in size. This was probably due to a better trained class of labour being required on the larger farms. On the larger farms the family labour and the operator's labour in particular was usually estimated at higher rates per month than on smaller farms. The average size of farm is shown in the final columns of Table 4. The variation in labour rates in the first section of Table 2 which cannot be accounted for by the difference in hours worked per man, was probably due to the factors just mentioned which cause the labour rate to rise with increases in the size of farm. The inclusion of farms in the sample with comparatively large acreage was partly responsible for the higher cost of labour per hour on farms on which all the work was done by horses compared with those which had 99 to 67% of the field work done by horses. The smaller farms show higher percentages of man labour spent on choring.

THE AGRICULTURAL OUTLOOK PROGRAMME

Considerable interest was arroused throughout Canada during 1934 by the appearance of a publication entitled *The Agricultural Situation.* That interest has been further stimulated by the release early this year of the second of such reviews under the revised title, *The Agricultural Situation and Outlook, 1935.* Since enquiries have been made concerning this undertaking, it was thought that some information on the subject might be of value to readers of the *Economic Annalist,* particularly those outside Canada. Many will be familiar with the programme in the United States; to them the method of conducting the undertaking in Canada may be of interest.

Object.—First, with regard of the object of such an undertaking, it should be noted that, while we have for years had well organized intelligence and statistical services, and in some instances periodic reviews of the agricultural situation, we have not had an annual appraisal of the industry as a whole; we have had nothing that corresponds to the inventory that any well-run business is accustomed to. The object, then, of such a programme is to fill a gap in our service and in doing so, to supplement and co-ordinate, rather than displace, existing activities.

The recipients of such a service are, of course, the farmers and others interested in agriculture. For the farmer it is hoped the Outlook report will provide information at a time when it can be used in making plans for crop and live stock production for the ensuing year or period of years. To others its principal value will be found in the provision of a comprehensive review of the status of an industry in which most of us have an interest, direct or indirect

Advisory Council Sponsors.—The work in this country is sponsored by the National Advisory Council on Agricultural Services. This body represents all Departments, Universities, Colleges, and Research bodies interested in the development of Agriculture. The council in 1932, and again in 1933, at general meetings heard recommendations from subcommittees that an agricultural outlook program be initiated. In response to such requests the executive of the Council in the fall of 1933 appointed a committee, two of whom represent the Departments of Agriculture and Trade and Commerce in the Dominion Government and the third the provincial agricultural institutions, to arrange for such a service.

The constitution of this "Agricultural Outlook Committee" is significant, for it recognizes the need for a co-operative approach to the conduct of this particular undertaking. The resulting programme is not the product of a single department or institution. The principle thus recognized was further emphasized by the Committee on the appointment of subcommittees. The latter in turn are made up of officials of the several departments at Ottawa that are in a position to contribute information or assistance. Moreover, the subcommittees are composed of men representing, as far as possible, the different divisions of agricultural activity. Thus on the 16 committees that prepared the 1935 report the Departments of Agriculture, Trade and Commerce, External Affairs, and Finance are represented, and in addition each committee has been selected so as to ensure that all phases of the production and marketing problem are adequately presented; the Experimental Farms Branch, the National Research Council, the Markets Divisions of the Department of Agriculture, together with the Commercial Intelligence Service, The Dominion Bureau of Statistics, the Entomological Branch, and the Economics Branch are represented. In addition, where an appreciation of the problem confronting agriculture depends upon a knowledge of the internal financial situation or upon information concerning developments in other countries, the appropriate departments are represented. Editorial and publicity committees insure satisfactory presentation and distribution of data.

Scope and Procedure.—The Outlook Committee in consultation with subcommittees decided that the report should summarize the general agricultural situation and outlook—domestic, empire and foreign—and then deal with specific agricultural

commodities. Subcommittees have been selected to give effect to this policy. The trend of business activity, employment, and international trade is considered in dealing with commodities and is featured in the general introductory sections.

The procedure followed has been to request the special committees to prepare reports on the subjects or commodities assigned them The members of each committee, who by virtue of their positions in the respective services are in possession of, or have access to, the best available information on the matter they are to deal with, bring such information to the committee. Where additional data are required the departments are requested to provide them. Reports, insofar as possible are uniform in type of content—each is intended to summarize production, distribution, storage holdings, prices, competition, and demand. Committees meet with one another when the matters dealt with are inter-related.

About a month has been allowed for the preparation of reports following which a general conference has been called. To this conference the provinces have been invited to send representatives. This year the reports were sent, in preliminary form, to provincial Departments of Agriculture for consideration prior to the Outlook Conference.

At this general conference each committee report is presented and analyzed. There is thus brought to bear upon the final report, not only the best efforts of those immediately concerned with the subject or commodity under consideration but also the opinions of those concerned with other phases of agriculture. The completed report thus represents the considered opinion of persons whose work brings them into intimate contact with all phases of the matter under review.

Passing reference should be made to the value of this final conference to those engaged in agricultural work. Offering as it does a chance to hear the whole situation reviewed it has given to the specialized worker an opportunity that has heretofore been lacking. If and when provincial representation at this gathering is more general, it should provide an opportunity for dealing with many matters related to agricultural development.

Printing and Publicity.—The final report has been printed in both English and French and widely distributed. In addition the press has been provided with summarized statements dealing with each phase of the report and these have been widely used. The co-operation of the Publications Branch of the Departments of Agriculture and the Publicity Division of the Department of Trade and Commerce has been most helpful in this connection. A National broadcast has been arranged each year with the assistance of the Canadian Radio Commission in which the "highlights" of the report were reviewed by the Deputy Minister of Agriculture, Dr. H. Barton

Extension Programme.—In the United States, where an Outlook report has been prepared for some years, the national undertaking has been supplemented by state reports and by a well organized programme of extension work. In Canada only two provinces, Nova Scotia and Saskatchewan, have so far undertaken such work and in these instances the work antedated the federal programme. In Nova Scotia the agricultural representative service has used both provincial and federal Outlook reports extensively, but in other provinces there appears to have been little concerted effort to popularize such information. The National Outlook Committee appreciates that it has some responsibility in this connection. An effort has been made this year to meet the situation in a measure. Supplementary data were prepared for the use of extension workers and an effort was made in a small way to demonstrate the value of Outlook information at farmers' meetings. This phase of the service should be developed, but maximum results are not to be expected until provincial reports are prepared and the whole programme, federal and provincial, is co-ordinated.

Summary.—The response to this programme has been very gratifying. The Agricultural Journals and other press have made extensive use of the material furnished and the demand from farmers and business leaders for copies of the report has been very satisfactory. Its place in Canadian Agriculture will likely be one of increasing importance.

ECONOMIC LITERATURE

MORTENSEN, W. P. Economic Considerations in Marketing Fluid Milk. Research Bulletin 125, Agricultural Experiment Station, University Wisconsin, Madison, Wisconsin.

This 56-page bulletin is divided into five sections: Market Price Plans and Policies, Distributors' Margins, Analysis of Distributor Costs and Profits, Public Control of Milk Distribution, and Competition of Evaporated Milk with Fresh Milk.

Under normal competitive conditions, the prices of the various types of milk products tend to move up and down in unison. Fluid milk prices while moving in sympathy are on a higher plain due in part to protection of various kinds which the producers of fluid milk have provided for themselves. During the depression period, the comparatively attractive fluid milk price induced fluid milk producers to increase their output and producers outside the fluid milk zone to break down the barriers which have kept them out of this field. The two factors together have produced a condition of heavy surplus on the fluid milk market with resultant chaos.

Analysis of Returns and Costs.—In comparing the conditions prior to the depression 1927-1929 with the depression years 1931-33, it is revealed that in six Wisconsin cities that "the distributors' margin was reduced only 0 2 cents per quart between these two periods, while the farmer's price was reduced 1 7 cents. The total reduction in the retail price during the period was 1.9 cents per quart. This pronounced decrease in price paid farmers compared with the reduction of distributors' margin, is apparently typical during periods of rapidly falling prices." Concerning distributors' profits, the writer states, "It is noteworthy that if profits of these companies had been cut in half for the six-year period (which would have left about the equivalent of a normal interest rate on money invested) it would have meant a saving of about one-fifth cent per quart sold at retail. While the importance of this is not to be neglected, it is evident that if any very substantial reduction in distributors' margins is to be achieved, other and larger savings must also be effected. These must come as the result of the elimination of inefficiencies and of unnecessary costs." An analysis of distribution of returns to farmers shipping to condenseries is summed up: "From this, it appears that farmers suffered doubly: First, by low prices paid by consumers; Second, by the fact that the farmers did not continue to obtain the same proportion of the consumer's dollar as they received before the fall in prices."

The relative prices of whole milk and evaporated milk have so moved during the past few years as to increase the per capita consumption of evaporated milk. This is a distinct blow to the fluid milk business as the evaporated product readily replaces the bottled milk when price differentials warrant.

Relatively high prices for fluid milk encourage substitution, reduce consumption, attract increased product to that market, induce competition from fields regularly outside the fluid milk production zones, and as the author states, "If producers of city milk lose sight of the fact that they are inseparably a part of the whole dairy industry they are bound to invite difficulty. A price structure built on quicksand is too insecure to serve dairymen properly who are in business on the basis of a long period."

Excessive operating costs in milk distribution can largely be traced to (1) under-capacity operation and (2) duplication of effort and equipment. To meet this situation, producers and consumers must choose between that system of milk distribution which operates with unnecessarily large concerns providing abundant service and that of a limited number of organizations under some kind of public control.

Public control may be of three types: (1) Public control with private ownership (under the A.A.A., this method is in operation with some degree of success in several states); (2) Public control with limited private ownership; and (3) Public ownership. Numbers 2 and 3 are considered to be suggestions for a permanent rather than a temporary control programme. It is believed that a programme such as will give farmers an opportunity to bargain with distributors directly or through strongly organized agencies would give as high a farmers' price as local and general conditions warrant.

NOTES

The First Annual Report of the Pigs Marketing Board for Northern Ireland has been issued recently. It is interesting to note the early decision of the Board "to start investigations and the collection of information on which to build up their policy; that any drastic immediate action was undesirable, and that for the moment no change in marketing methods should be made, but that dead pig prices should be fixed in negotiation with the Bacon Marketing Board (who represented the curers). This decision was taken with a view to ridding the industry of the curse of pig price variations from week to week and to enable producers to take advantage of the higher pork price which curers could afford to pay as a result of the reduction of bacon imports."

Mr. A. Leitch, formerly Professor of Agricultural Economics, Ontario Agricultural College, Guelph, and more recently associated with the development of the tobacco industry in Norfolk County, Ontario, has been appointed Chairman of the Dominion Marketing Board. He will, however, retain some connections with the tobacco business. Dr. H. Barton, who was formerly chairman of the Board, has asked to be released from the duties of this position as the duties of the Deputy Minister of Agriculture are onerous and the responsibilities which are attached to the chairmanship of the Board are rapidly increasing.

The annual index of prices of agricultural produce in Great Britain (1911-13 = 100) was 114 in 1934 compared with 107 in 1933. If allowances are made for emergency payments under the Wheat Act of 1932 and the Cattle Industry Act of 1934, the index would be 119. The chief factors responsible for the rise in the index were higher prices for fat sheep, fat pigs, milk, wool, hay, potatoes, barley, and oats. Lower prices were recorded for fat cattle, wheat, dairy produce and fruit.

Mr. H. R. Hare, formerly in the Department of Animal Husbandry, University of British Columbia, has joined the staff of the Economics Branch of the Department of Agriculture, Ottawa. While on the staff of the University of British Columbia, Mr. Hare conducted a Dairy Farm Management study based upon 180 farms. Data were obtained over an eleven year period, 1921-31.

The monthly letter of the Canadian Bank of Commerce for December emphasizes the importance of farm purchasing power. A new index of Canadian farm purchasing power has been constructed which records the fluctuations quarter by quarter during the past eight years. In 1934 the index was 64.64 at the end of the first quarter, 65.27 at the end of the second quarter, and 67.51 at the close of the third quarter.

Creamery butter in storage in Canada February 1, 1935, amounted to 22,344,540 pounds as compared with 31,543,203 pounds as of January 1, and a five-year average of 16,072,031 pounds. While the stocks showed a decrease of 29.7% during January, holdings on February 1 were 52.7% above those on hand at the same date in 1934.

Total expenditures of the United States Agricultural Adjustment Administration from May 12, 1933, to December 31, 1934, were reported to be $773,983,535 of which $527,501,795 represent rental and benefit payments and $170,296,958 for surplus removal operations. The balance represented the cost of administration. Processing taxes have returned $640,871,403.

Mr. S. C. Hudson, Economics Branch, Department of Agriculture, Ottawa, has been granted leave of absence for the purpose of continuing work in the Graduate School at Cornell University.

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RASPBERRY NUTRITION

I. SEASONAL VARIATION OF PLANT NUTRIENTS IN RASPBERRY PLANTINGS UNDER DIFFERENT CULTURAL TREATMENTS

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INTRODUCTION

An investigation into the causes of raspberry failures and low yields in certain sections of the Lower Mainland of British Columbia soon disclosed the fact that the problem of soil deficiencies in available nutrients was of paramount importance. Having no previous work of this nature for a basis of comparisons it was decided to make a careful study of the seasonal variations of plant nutrients under different cultural treatments.

PLAN OF EXPERIMENT AND PLOT TREATMENT

Plot Treatment.—In the spring of 1930 five blocks of Cuthbert Raspberries were planted at the Dominion Experimental Farm, Agassiz. In these blocks twenty-eight uniformly distributed plots were selected. Each plot consisted of two adjacent 50-foot rows, each containing twenty plants with buffer rows on each side of the plot. Rows were spaced 7 feet 6 inches apart. The area was clean cultivated in 1930. In 1931 the various treatments were commenced, including cover cropping with clover, rye, and vetch, and fertilizing with barnyard manure, complete artificial fertilizer and sodium nitrate. These treatments, together with check plots receiving no treatment, were replicated once in each of the five blocks and allocated so that the maximum distribution was obtained over the whole area.

Rye, vetch, and clover were seeded at 112, 112, and 20 lbs. per acre respectively on May 9. Well-rotted barnyard manure was applied at the rate of 13 tons per acre on March 28. Complete fertilizer (5-10-6) was applied at the rate of 750 lbs. per acre on April 3. Nitrogen fertilized plots were treated with an application of nitrogen equivalent to that given in the complete fertilizer on May 9. Plots which were not cover cropped were cultivated during the growing season to keep down weeds. The area was plowed as a whole on April 4, disced April 20, hoed May 13, cultivated May 20, disced July 21, hoed August 10, disced August 13. Rye was disced down July 21, clover and vetch were turned under August 13.

Sampling.—Soil samples from each plot were taken during 1931 in the months of March, May, July, September, November, and also again in March, 1932. All samples were air dried.

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These samples were brought to the University of British Columbia and analysed in the Horticultural (Plant Nutrition) laboratories. Thus throughout the year the effect on the available food supply of the various cover crops and manures was obtained.

Soil Analysis.—The soil used was a fine silt carrying with it a considerable amount of clay. An analysis of this soil by Shutt (*9*) in 1893 was as follows:—

Water	3.24%	Magnesia	1.45%
Organic volatile matter	6.96%	Potash	0.33%
Clay and sand	75.14%	Soda	0.17%
Oxide of iron and alumina	10.83%	Phosphoric acid	0.25%
Lime	0.94%	Carbonic acid	0 46%
		Nitrogen	0.148%

For the present experiment the method used to obtain soil samples was that outlined by Russell (*8*). On each sampling date moisture determinations were made and are indicated below:—

Mar. 14	29.6%	July 23	22.4%	Nov. 24	27.5%
May 20	25.1%	Sept. 23	24.4%	Mar. 13	27.5%

Available nutrients were determined in the soil solution.

Method.—The method of obtaining the soil solution was one of displacement, outlined by Burd and Martin (*2*, *3*), in which 2 kilos of soil are packed into brass tubes 17 inches long and 3 inches in diameter: at the bottom is a brass screen covered with filter paper, below which a tube leads out; the top is fitted with a screw cap and tube so that air pressure can be applied. 400 cc. of water are poured on the soil and air pressure increased usually up to 100 lbs. till the liquid runs through.

The solution is collected in 10 cc. fractions: the first lot are uniform in composition as shown by their electrical conductivity and are assumed on good experimental grounds to represent the true soil solution. This method according to Russell is the most convenient of the various methods described for displacing the soil solution (*8*). A battery of 6 extraction tubes was used.

It is of interest to note here that the average time required to displace the soil solution was about 3 hours, and that all samples taken in March, 1931, and March, 1932, took 1½ to 2 hours longer to be displaced than samples taken at any other time, while samples taken in July were without exception the fastest. All displacements were made at a moisture content of 27%.

The determinations made on the soil solution were: Electrical conductivity, pH, and the following ions: nitrates (NO_3), potassium (K), phosphates (PO_4), magnesium (Mg), chlorine (Cl), bicarbonates (HCO_3), calcium (Ca), and sulphates (SO_4). (*1*,*4*,*7*,*5*).

Conductivities were read as ohms resistance of the solution at 20° C. pH was determined with a quin hydrone electrode and checked colorimetrically.

PRESENTATION OF DATA

Nitrates

TABLE 1.—NITRATES IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	24	300	62	155	89	25	109 3
Clover	23	269	23	272	105	33	121 1
Vetch	26	297	117	202	133	25	133 3
Fertilizer	33	346	151	295	172	18	169.2
Manure	40	557	238	346	216	19	236.0
Nitrogen	44	415	254	295	177	17	200 0
Check	51	399	221	399	199	30	216.5
Mean average	34 4	369	152.3	266 3	156	23 9	168

Nitrates show (in Table 1) a very well defined seasonal trend. In March they are very low, in May they are high; in July they fall to a low figure and in September they are high again. In November they fall off and continue falling until a very low concentration is reached the following March.

While there is some variation in the initial March 14th determinations before treatments, it is obvious that the very low July concentration of nitrates under rye, clover and vetch is due to the feeding of these crops. Clover appears to reduce the nitrates the most during the summer period, but after plowing the crops under, rye seems to be the least advantageous.

Fertilizer, manure and nitrogen applications appeared to maintain to some extent a higher concentration of nitrates than would have otherwise prevailed during the low July period. The high figures shown in the check plot are surprising, but it is to be noted that in the initial March analysis they are high.

Phosphates

TABLE 2.—PHOSPHATES IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	7 80	5.90	6.76	6.66	6.76	7.15	6.84
Clover	6.82	7.32	6.99	6 99	7.82	8.84	7.33
Vetch	6.48	7.00	7.70	7.76	8.15	8.97	7 68
Fertilizer	8 89	9.25	9.62	9.81	10.00	9.42	9 49
Manure	5.74	6.36	7.15	6.61	6.73	7.00	6.59
Nitrogen	7 84	7.84	8.86	6.92	7.84	8.71	8.00
Check	5.47	7.62	7.62	7.62	7.62	7.62	7.26
Mean average	7.01	7.33	7.81	7.48	7 70	8.24	7.60

The figures shown in Table 2 for phosphates are undoubtedly a little too high. Some silica may have been included as phosphate. However, for comparisons they are reliable and indicate relative values.

There appears to be no well defined seasonal trend or fluctuations as with nitrates. The complete fertilizer treatment gave slightly higher values, which mav be significant. The stability of the check plot is noticeable, showing that there has been less interference in ionic relationships than where manurial applications and treatments were made.

Potassium

TABLE 3.—POTASSIUM IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	7	16	6	10	9	7	9.2
Clover	6	14	6	12	10	9	9 5
Vetch	7	12	10	12	7	8	9.3
Fertilizer	7	17	12	12	9	8	10 8
Manure	7	22	10	20	11	5	12 5
Nitrogen	8	25	11	20	11	9	13 8
Check	8	15	12	15	11	8	11 5
Mean average	7	17	10	14	10	7.7	10 9

The values for potassium as given in Table 3 are interesting. The same seasonal trend is followed as with nitrates. Plots growing cover crops show a lower concentration than those otherwise treated. It is especially noteworthy that the nitrogen only application increased available potash over any other treatment. The lowness of the potassium throughout is noticeable and would indicate that any treatment whereby available K is increased would benefit crops.

Calcium

TABLE 4.—CALCIUM IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	70	200	89	86	82	21	91.4
Clover	57	117	50	87	52	24	64 5
Vetch	54	103	82	80	74	22	69.2
Fertilizer	60	151	122	80	106	31	91 7
Manure	75	250	107	136	118	20	117.8
Nitrogen	78	138	108	88	78	32	87.0
Check	74	173	132	76	97	26	96 5
Mean average	67	163	98.7	90.5	86.9	25 2	88.4

The seasonal trend in calcium (Table 4) differs from that of nitrates in that while the May figures are high there is a gradual decline from then on, progressing with the season. The concentration under cover crops is

less than without such treatment. Clover again shows the minimum summer value for this ion.

Magnesium

TABLE 5.—MAGNESIUM IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	7	23	9	7	6	4	9.35
Clover	6	7	6	8	5	4	6 00
Vetch	13	32	14	21	19	3	17.00
Fertilizer	11	29	13	7	9	5	12.33
Manure	7	20	16	13	11	6	12 17
Nitrogen	15	21	27	31	21	15	21 60
Check	5	14	14	8	13	4	9 66
Mean average	9 14	20 81	14 14	13.57	12	6.83	12 60

Magnesium (Table 5) shows the same general behavior as calcium. Values decrease as the season advances. Individual treatments show more variation than they do with calcium. Again clover appears to utilize magnesium more heavily than other crops, whereas vetch uses this element sparingly. Similarly to potassium, the nitrogen treated plots show enhanced magnesium over other treatments.

Sulphates

TABLE 6.—SULPHATES IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	11	22	9	17	11	8	12 2
Clover	10	9	8	8	5	6	7 5
Vetch	17	10	8	8	8	6	9.5
Fertilizer	15	36	36	32	12	7	23 0
Manure	14	13	8	10	7	6	9 7
Nitrogen	10	8	11	11	10	7	9 5
Check	10	10	10	33	11	4	13.0
Mean average	12 4	15 3	12 9	17	9.1	6 3	12 2

The same general trend is followed with sulphates (Table 6) as in the case of nitrates. They are highest in May and September, although there are some slight inconsistencies. The May concentration in some cases is not appreciably greater than that of March, 1931. The complete fertilizer prevented the July minimum value being reached. It would appear that sulphates are not so readily lost from the soil solution during the winter months as are calcium and nitrates. Under clover, again the lowest concentration appears.

Bicarbonates

TABLE 7.—BICARBONATES IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	29	22	37	27	27	29	28 5
Clover	35	27	37	24	24	17	27.3
Vetch	29	17	27	22	22	17	22 3
Fertilizer	39	29	41	24	24	24	30 2
Manure	34	27	27	27	27	29	28 5
Nitrogen	46	44	44	37	37	37	40 3
Check	34	27	29	29	24	24	32 8
Mean average	35 1	27.6	34.6	27	26 4	25 3	30 0

Considerable fluctuation is shown with bicarbonates (Table 7). In general it may be deduced that when ions previously mentioned are high, bicarbonates are low, and vice versa. This ionic relationship applies particularly to the anions NO_3 and SO_4. The plots under cover crop show increased HCO_3 over the others, except that treated with sodium nitrate. The effect of NO_3 in increasing root growth and the resulting added CO_2 production may account for this.

Chlorine

TABLE 8.—CHLORINE IN SOIL SOLUTION IN PARTS PER MILLION

Soil treatment	Dates samples taken						Total average for treatment
	Mar 14, 1931	May 20, 1931	July 23, 1931	Sept. 23, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	32	14	16	14	10	30	19 6
Clover	24	36	12	16	12	34	22 3
Vetch	26	24	14	10	20	28	20 3
Fertilizer	22	48	42	16	12	28	28 0
Manure	20	28	22	18	14	32	22 3
Nitrogen	20	22	16	10	18	26	17 0
Check	24	18	22	12	12	24	18.7
Mean average	24	27 1	20 6	13.7	14	29	22 0

The chlorine ion shows no consistent behavior (Table 8). It is noticeable that it is high during the early spring when other ions are low, so it is probably a product of rainfall. During the summer months cover crops seem to reduce it more than other treatments, and clover more than the other cover crops.

Total Ions

Total ions were measured electrically, Table 9 being a record of the specific resistance offered by the soil solution. The larger the figure the weaker is the concentration of the soil solution.

TABLE 9.—SPECIFIC RESISTANCE (OHMS) OF SOIL SOLUTIONS UNDER DIFFERENT MANURIAL TREATMENTS

Soil treatment	Dates soil samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 24, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	7200	1350	2100	3525	5100	7800	4507
Clover	7800	1950	5700	2100	4500	6700	4786
Vetch	7300	2325	4950	3000	3550	7350	4746
Fertilizer	6900	1125	2250	2100	3150	7950	3920
Manure	7200	1650	2175	1875	2175	6450	3580
Nitrogen	6450	1420	2250	2175	3000	7500	3800
Check	6125	1875	2625	1875	3850	6450	3800
Mean average	7000	1675	3160	2380	3620	7180	4160

The seasonal variation of total ions follows the trend of the nitrates, the total concentration being low in March, high in May, low in July, high in September, and from then on there is a gradual falling to a low point the following March. Clover reduces the available nutrients to a very low figure in July. Rye is not so exhaustive as other green manures while actually growing, but as indicated by September and November measurements, it is not so beneficial when turned in. Complete fertilizer, manure, and nitrogen all prevented the July minimum to some extent, manure showing the greatest effect.

Reaction of Soil Solution

TABLE 10.—pH VALUES OF SOIL SOLUTION UNDER DIFFERENT TREATMENTS

Soil treatment	Dates soil samples taken						Total average for treatment
	Mar. 14, 1931	May 20, 1931	July 23, 1931	Sept. 24, 1931	Nov. 24, 1931	Mar. 13, 1932	
Rye	5.6	5.6	6.0	5.9	5.9	5.6	5.72
Clover	5.6	5.5	6.3	6.0	5.8	5.6	5.80
Vetch	5.8	5.7	6.3	5.7	5.7	5.5	5.75
Fertilizer	6.0	5.9	6.1	5.9	5.9	5.8	5.94
Manure	5.9	5.7	5.7	5.8	5.8	5.9	5.80
Nitrogen	5.9	5.8	6.0	5.8	5.8	5.85	5.85
Check	5.8	5.7	5.7	5.6	5.6	5.80	5.70
Mean average	5.79	5.66	5.97	5.79	5.79	5.71	5.80

Table 10 shows that in general the acidity decreases during the summer. It decreases more under cover crops than without, and less under rye than under clover or vetch.

DISCUSSION

The relatively long period necessary to extract the soil solution in both March, 1931, and March, 1932, shows that at these periods the soil was in a poor physical condition (deflocculated). This deflocculated condition can readily be accounted for by the low calcium content and low content generally of flocculating ions. A fall application of lime should prove very beneficial in preventing this winter poor soil condition.

The rapid leaching in the winter of all nutrients strongly indicates that some method of preventing these losses should be practised in wet, mild climates such as the Lower Mainland of British Columbia. The use of winter cover crops is therefore recommended. Cover crops grown at this time offer no serious competition to the main crop and when the cover crop is plowed under the nutrients used by it, and so prevented from leaching away, are returned to the soil. Planting in the early fall should also give them a good start as the analyses showed large amounts of available nutrients present at this time.

Benefits of Cover Crops.—The less acid soil solution under cover crops, Table 10, is significant. It is now well known that damage due to acidity is often caused, not by the acidity (H-ion) directly, but rather the lowering of the pH brings into solution toxic substances in the soil which under less acid conditions are insoluble and therefore harmless, *e.g.*, aluminum. The extra CO_2 excreted from the roots of the cover crops, as observed in Table 8, increases the bicarbonate ion which must replace, in the soil solution, the absorbed strong acid radicles such as SO_4, NO_3, Cl, etc., with a very weak one. Hence the pH of the solution goes up (*6*).

On the other hand, from unpublished work done in this laboratory there is evidence that cover crops render alkali soils less alkali. Alkalinity often causes damage indirectly by making nutrients insoluble which are needed by the plant. Under such circumstances, making the soil solution more acid by growing cover crops tends to render certain nutrients more available. Iron is a good illustration of a nutrient so affected. In alkali soils even small differences may be very significant. There is no way of making actual determinations on the soil solution immediately at the point of contact with the root. This zone is the important one and the reaction at this point is very probably quite different to the reaction of the extracted solution from the soil as a whole. At this zone of contact CO_2 is bound to be relatively concentrated due to its continued excretion from the root, compared to that which is some distance away. In alkali soils the carbonates which are strongly alkaline usually exist. Passing CO_2 into a solution containing carbonates will change some of the carbonate over to the bicarbonate, and the resulting equilibrium mixture will be fairly close to neutrality. The question arises then as to whether any plant is ever actually feeding in a very alkali medium, even though the pH of the soil may so indicate.

Harmful Effect of Cover Crops.—Due to nutrients being lower under cover crops than under other treatments, the danger of establishing a cover crop in a poor soil where nutrients are low, is obvious. Such a soil should first be built up with barnyard manure or artificial fertilizer before sowing the cover crop. Of the cover crops used, rye seems the least competitive to the main crop, and clover the most competitive.

On soils where inorganic nutrients are not deficient, the advantage of building up humus and improving the physical condition of the soil is well known.

Application of Fertilizers.—On reasonably good soils no spring application, unless a very early one, of readily available nitrogen would appear

to be of value. The May concentration of nitrates (also most other nutrients) is normally high. For crops making growth in June and July, this would appear to be the time when an application of available nitrogen is needed as nitrates are normally very low at this time. This would be particularly true in a soil not especially rich, where cover crops are being grown, where a lawn is in the process of making or being maintained, or in the establishment of any grass lands.

It is of especial interest to note that a spring application of sodium nitrate did not appreciably increase the nitrates in the soil solution in this experiment, but did increase the available potash and, to some extent, the magnesium. This appears to be a base exchange phenomenon where the nitrates went quickly into solution and were used up by the plant roots, whereas the sodium replaced potash from the solid phase of the soil. The potash so released then entered and became part of the soil solution.

The fact that such a situation here occurred leads to the supposition that this may frequently occur on soils, particularly where minerals are not especially deficient. Very probably one of the benefits derived from adding different fertilizers on relatively good soils comes from increasing the potash by the method suggested, rather than by increasing the other elements. Analyses of soils universally show relatively low figures for available potash, whereas the total amounts of potash in agricultural soils is usually high. Any method of increasing the concentration of the potassium in the soil solution would then be expected to give better growth, even where fairly good growth was taking place. Investigations as to methods of releasing the potash already present in the solid phase of the soil should be very fruitful.

Index of Soil Fertility.—While the data obtained in this work are obtained from a soil which shows no deficiency in plant nutrients, nevertheless, this soil is not particularly high in such constituents. It has, however, good recuperative powers in its ability to restock the soil solution, as evidenced by the low March and July figures, followed by the high figures in the May and September analyses. The values obtained then, are considered just about marginal for safety of good growth.

Definite Need Fulfilled.—Finally in this study a very definite need has been fulfilled in that a "yard stick" has now been provided as a basis for a comparison of soils growing raspberries in the Lower Mainland area of British Columbia.

With such a series of analyses available as a standard, it is possible to use these data in comparing the analysis of the soil solution of any soil in the lower mainland where the displacement has been made at the same corresponding time of the year and at the same, or calculated to the same, moisture content as shown in the tables obtained.

If it is found on making such a comparison that any one or more of the nutrients fall much below the values for those nutrients shown in the tables, the particular soil in question is in need of supplementary treatment to increase the concentration of the soil solution in respect to the nutrient deficiencies shown.

LITERATURE CITED

1. Am. Assoc. of Agr. Chem. (A.O.A.C.), Wash., D.C.
2. Burd, J. S. and J. C. Martin. Water displacement of soils and the soil solution. Jour. Agri. Sci. *13* : 1923.
3. ——————————. Secular and seasonal in the soil solution. Soil Sci. *18:* No. 2. 1924.
4. Cameron and Failyer. Jour. Am. Chem. Soc. *25* : p. 1068.
5. Hibbard, P. L. Methods of Chemical Analysis. Univ. of California. 1923.
6. Hoagland, D. R. The effect of the plant on the reaction of the culture solution. Univ. of Calif. Tech. paper No. 12. 1923.
7. Parkes, F. W. and J. F. Fudge. The colorimetric determination of organic and inorganic phosphorus in soil extracts. Soil Sci. *24* : 109-117.
8. Russell, E. J. Soil conditions and plant growth. Longmans Green & Co. 1927.
9. Shutt, F. T. Report of the Dominion Chemist. Central Expl. Farm, Ottawa. 1893.

Résumé

Nutrition du framboisier. G. H. Harris et J. J. Woods, Université de la Colombie-Britannique, Vancouver, C.-B.

L'étude dont il est fait rapport portait sur des échantillons de terre pris dans une plantation de framboisiers à Agassiz, C.-B. On a constaté que les principes nutritifs du sol sont rapidement emportés par les eaux en hiver et l'emploi de plantes-abris en hiver est recommandé, sauf sur les sols pauvres. Les applications de nitrate de soude au commencement du printemps n'ont pas beaucoup augmenté la quantité de nitrates dans la solution du sol, mais elles ont augmenté la quantité de potasse assimilable et, jusqu'à un certain point, celle de magnésium. Ces expériences ont été utiles en fournissant un guide touchant les éléments nutritifs nécessaires dans les sols affectés à la culture du framboisier dans ce district.

MALLING STOCKS AND FRENCH CRAB SEEDLINGS AS STOCKS FOR FIVE VARIETIES OF APPLES. I.

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[Received for publication January 12, 1935]

A few years ago it became evident that the Malling vegetatively propagated apple stocks were being found very useful under conditions of soil, culture and climate existing in England. It became imperative, therefore, that the most promising of these clons should be evaluated as stocks for apple trees in Canada.

MATERIALS

In the spring of 1927 the Ontario Horticultural Experiment Station imported from the East Malling Station the following budding stocks: 200 each of Malling XVI, I and II; and 100 of Malling IX. These stocks were budded in August of the same year to five important local varieties, viz., R. I. Greening, Melba, Delicious, Spy and McIntosh, equal numbers of buds of each variety being set in each stock. A good stand of trees was obtained and in the fall of 1929 the best trees of each variety were planted in an orchard in a comparative test with commercial nursery trees on French Crab seedling roots which had been selected for uniformity in the nursery. All of the latter were budded trees except Spy which was grafted on whole roots. Trees on standard stocks, French Crab and Malling XVI, were planted 39 feet apart each way. Filler trees, Malling I and II alternating, were planted only *between* standard rows and not *in* the standard rows, Malling I being semi-standard, *i.e.*, in the centre of the square made by two French Crab trees on one row and two Malling XVI trees[2] on the adjacent standard row. This arrangement allows for an analysis of results by Students' Method, 16 pairs being available for each variety. Trees on Malling IX being few in number were planted at one side of the orchard and are therefore not included in the analysis.

The soil is a fine sandy loam, low in organic matter and readily available phosphorus and potash. The land is slightly rolling and there is a low area cutting across one corner of the orchard. Clean cultivation plus cover crops is the method of culture followed. No manure has been used and the only mineral fertilizer applied was in the spring of 1934: 600 lbs. of acid phosphate and 300 lbs. of sulphate of potash per acre. Some potash starvation symptoms have shown up, particularly in the variety R. I. Greening.

Measurements

No growth records were kept in the nursery. In the spring of 1930 all trees were pruned moderately to encourage the development of satisfactory heads. These prunings were not weighed but since that time weight of prunings from individual trees has been recorded. Trunk measurements have been taken at a marked point above the wire guards

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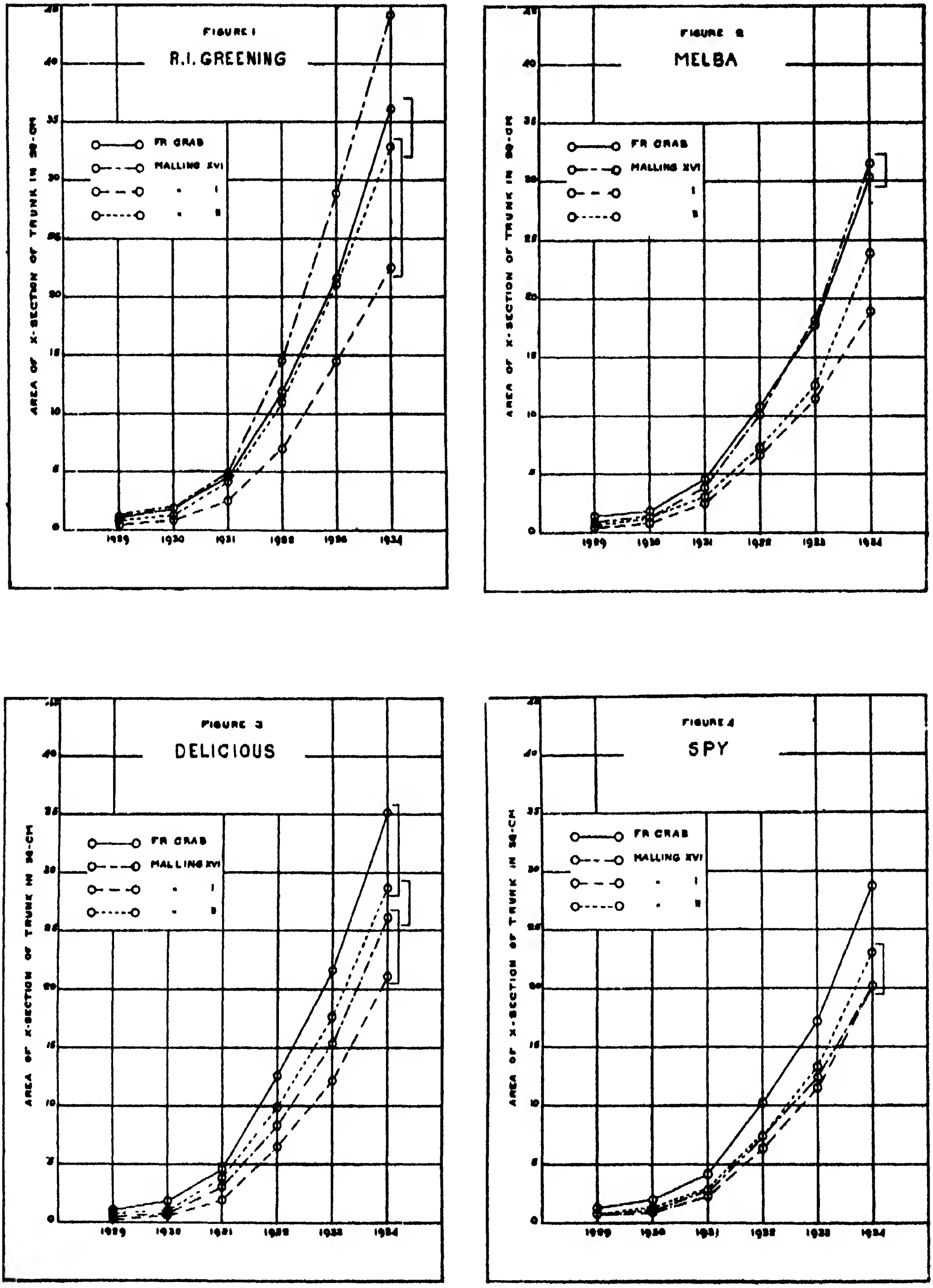
[2] When trees are referred to as French Crab trees, Malling XVI trees, etc., it is to be understood that the trees are worked on these stocks.



FIGURES 1–4. Comparative tree size of R. I. Greening, Melba, Delicious and Spy on four stocks. Yearly total area of cross-section of trunk, means of 16 trees of each variety on each stock being plotted. 1934 measurements within brackets are not significantly different.

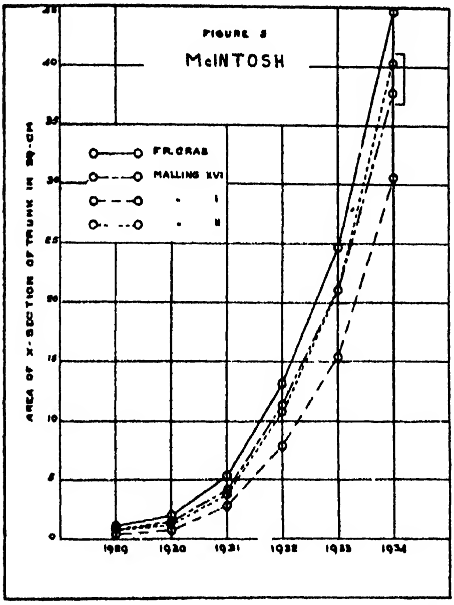


FIGURE 5. Comparitive tree size of McIntosh on four stocks. (Plotted by same method as Figures 1–4).

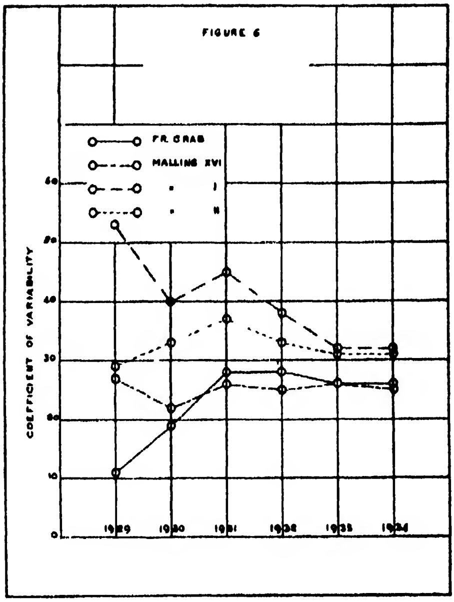
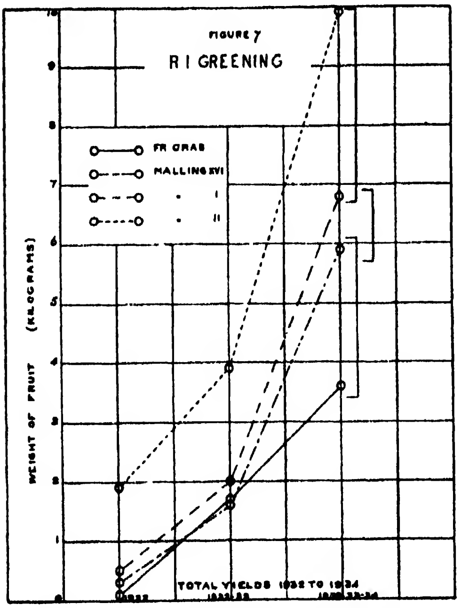
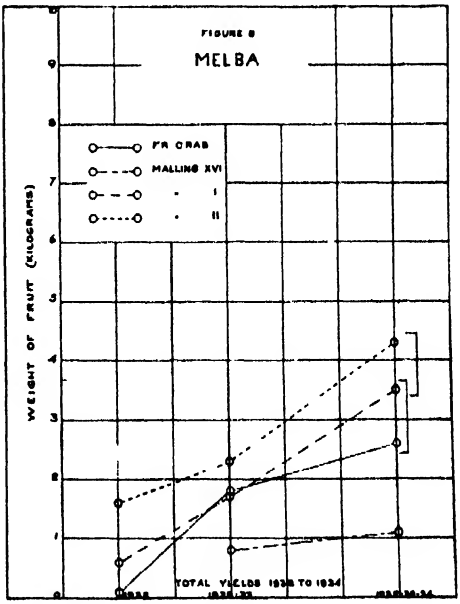


FIGURE 6. Yearly coefficient of variability in tree size, mean of five varieties.





FIGURES 7–8. Total yield of fruit, mean of 16 trees. Total yields up to and including 1934 which are bracketed together are not significantly different.

(rodent protection) about 16 inches from the ground. The area of cross-section of trunk has been computed from diameter and circumference measurements, the latter measure being used during the past three years. Counts of blossom clusters on each tree are being made until the variety begins to bear a measurable amount of fruit. Up to the present time number as well as weight of marketable fruits has been recorded for each tree.

RESULTS

Growth

In so far as area of cross-section of trunk can be used for that purpose, the comparative tree sizes over the five year period are shown in Figures 1–5. Cross-sectional area of trunk is certainly a better measure of comparative tree weight than is circumference (or diameter) as may readily be determined from Table 12 in New York (Geneva) Tech. Bul. 164 (Collison and Harlan). Those stocks which produced trees not significantly different in size at the end of 1934 are bracketed together at the extreme right of the figures. Malling I stock has given the smallest tree with all scion varieties, though in Spy it now equals Malling XVI. Malling I trees grew poorly in the nursery and as a result started in the orchard at a considerable size handicap. In R. I. Greening and Melba, the two most precocious varieties, Malling XVI trees are significantly larger than Malling II trees but in the other three varieties size differences are reversed but not significant. French Crab trees are significantly larger than Malling XVI trees in Delicious, Spy and McIntosh, while in Melba differences are insignificant and in R. I. Greening, Malling XVI trees are significantly larger than French Crab trees even though more fruit and prunings have been taken from the former. On first thought it seems unfortunate that there were size differences between the lots of trees at planting time but it must be pointed out that, with the exception of the French Crab trees, all trees were grown side by side in nursery rows and that therefore size differences in the fall of 1929 were probably characteristic of the stock on this particular soil. Undoubtedly the French Crab nursery trees were grown under better conditions of fertility than the trees on Malling stocks and thus started in the orchard with some slight advantage over the latter. Considering Delicious, Spy and McIntosh varieties French Crab trees are larger than Malling XVI trees but being also larger at planting time, the growth rate over the five-year period in the orchard as determined by the Geometric Mean formula, $\frac{\text{Increase}}{(t_2 - t_1)\sqrt{\text{original} \times \text{final}}} \times 100\%$, is greater for the Malling XVI trees. (Moffat (*1*) has shown that the Geometric Mean formula gives a satisfactory measure of growth rate.)

Growth Rates, 1929–1934.
Based on cross-section area of trunk, each figure being the mean of 16 trees

	French Crab	Malling XVI
Delicious	110	127
Spy	90	96
McIntosh	125	127

In Delicious and Spy the differences are significant, but not in McIntosh. However, the growth rate for the same trees from the fall of 1933 to the fall of 1934 is practically the same for these two stocks. This indicates that while Malling XVI trees tended to catch up to

French Crab trees in the early years in the orchard they have now ceased to grow at a faster rate than the latter. Fruit production has interfered with growth rate in R. I. Greening and Melba to such an extent that the figures would mean very little.

The pruning in this orchard was the minimum consistent with the development of reasonably strong well-balanced heads. All pruning has been done by the writer. Table 1 illustrates the inevitably heavier pruning given to the larger trees within a given variety, there being only one exception, viz., Spy on Malling XVI and Malling II which are very little different in size of tree or weight of prunings. Pruning, therefore, tended to minimize differences in this stock experiment and probably in all other experiments where growth differences are obtained. In a like way pruning is also a factor in reducing the variability of trees within a plot. It is of interest to note that the pruning given these trees has been very much less severe than that given some trees of Lane's Prince Albert of about the same age and size in a stock experiment at the East Malling Station (*2*).

TABLE 1. WEIGHT OF PRUNINGS, MEAN OF 16 TREES, 1931-34 INCLUSIVE (GMS.)

	French Crab	XVI	I	II
R. I. Greening	369	1053	363	656
Melba	531	538	189	306
Delicious	485	371	239	449
Spy	369	196	134	187
McIntosh	644	396	282	407

Variability

The coefficients of variability in cross-section area of trunk, means of five varieties, are given in Figure 6. French Crab trees started out very much more uniform than the trees on the Malling stocks but during the first two years they increased in variability to a point slightly above the Malling XVI trees and are now only slightly less variable than Malling I trees which were extremely variable when planted. During the past year the coefficient of variability has not changed to an appreciable extent for any of the stocks. It is unfortunate that the trees on Malling stocks were less uniform to begin with than those on French Crab seedlings as this condition makes it hazardous to make comparison as to variability in the orchard. However, in Melba, French Crab and Malling XVI trees, beginning their life in the orchard with C.V.'s of 18 and 20 respectively, had C.V.'s of 32 and 30 in the fall of 1934 indicating that the vegetatively propagated stock, Malling XVI, had only slight effect in making the trees on it more uniform. The writer feels reasonably certain that scion rooting has not been a factor in creating additional variability as he has failed to find more than a mere trace of scion roots on a very few trees.

Yield of Fruit

R. I. Greening and Melba are the only varieties which have produced an appreciable amount of fruit. They began bearing in the third year in the orchard. The comparative yields on the various stocks are shown in Figures 7 and 8, those within a given bracket being insignificantly different in total yield up to and including 1934. Malling II trees have produced

the most fruit but considering their smaller size (Figures 1 and 2) Malling I trees have yielded well. In R. I. Greening, Malling XVI trees have produced more fruit than French Crab trees but positions are reversed in Melba. In Delicious and McIntosh, all stocks ripened a few fruits in 1934 except Malling XVI. Spy has borne no fruit yet.

Malling IX

While the number of trees on Malling IX, classed as a very dwarfing stock, are very small, data on these trees are included here as they furnish some indication of the behaviour of this stock (Table 2). Melba has been dwarfed to a very marked extent, R.I. Greening, Delicious and McIntosh, to a lesser degree and Spy has not been dwarfed at all (See Figure 4) even though it has borne a few fruits beginning in 1932, the third year in the orchard. With all varieties this stock has induced earlier bearing and up to date the yields of R. I. Greening and Melba are a good deal heavier than on any of the other stocks. The fruits are also much better coloured than those from trees on the other stocks. Trees on Malling IX must be kept staked or trellised as the union is not strong. One Delicious tree which became loose from its stake was broken off at the union by wind.

TABLE 2.—GROWTH AND YIELD OF TREES ON MALLING IX

	No. of trees	Mean area of X-section of trunk 1934 (sq. cm.)	Yield of fruit per tree up to and including 1934 (kgms.)
R. I. Greening	3	18.1	14.5
Melba	6	9.8	10.2
Delicious	3	19.9	5.3
Spy	9	28.7	1.5
McIntosh	4	18.1	4.9

SUMMARY

This is a report on the behaviour of R. I. Greening, Melba, Delicious, Spy and McIntosh on French Crab seedlings, and Malling stocks, XVI, I and II up to the end of the fifth year in the orchard. There are 16 trees of each variety on each stock. Malling I has given the smallest trees, French Crab seedlings have produced the largest trees in three varieties and Malling XVI, the largest trees in two varieties. In three varieties trees on Malling II are larger than those on Malling XVI. Pruning weights show the possible reduction by pruning of (1) growth differences between trees on the various stocks and of (2) variability between trees within a given kind or treatment. Trees on French Crab seedlings which started in the orchard as very uniform trees are now just as variable as the trees on Malling XVI which started out very much less uniform. R. I. Greening and Melba are the only two varieties which have produced an appreciable amount of fruit. In both varieties trees on Malling II have produced the most fruit with Malling I trees coming next in order. In R. I. Greening, trees on Malling XVI have outyielded those on French Crab seedlings but in Melba the order is reversed. At one side of the orchard there are a few trees of the same varieties on Malling IX. This stock has induced different degrees of dwarfing in the various varieties,

has given better yields per tree than any of the other stocks, and produces exceptionally well coloured fruit.

ACKNOWLEDGMENT

The writer wishes to thank Director E. F. Palmer and Messrs. Dickson, Strong and vanHaarlem for advice in conducting this stock test and for assistance in the preparation of the manuscript. To Professor R. C. Moffatt of the Ontario Agricultural College the writer is indebted for advice on measurements and statistical analysis.

LITERATURE CITED

1. Moffatt, R. C. The use of the geometric mean in determining growth rates. Sci. Agr. *13*; 5 : 342-343. 1933.

2. Hatton, R. G. The influence of root stock upon the tree fruits. The Fruit Grower, Fruiterer, Florist and Market Gardener. Oct. 18, 25 and Nov. 1, 1923.

Résumé

Valeur des pousses de Malling et des égrins de pommiers sauvages français employés comme sujets pour cinq variétés de pommiers. 1. W. H. Upshall, station expérimentale d'horticulture, Vineland Station, Ont.

C'est là un rapport de la façon dont se sont comportées, jusqu'à la cinquième année de culture dans le verger, les variétés R.I. Greening, Melba, Délicieuse, Spy et McIntosh, greffées sur des sujets d'égrins de pommiers sauvages français et de Malling XVI, 1 et II. Il y a 16 arbres de chacune de ces variétés, sur chaque sujet. Le Malling I a donné les plus petits arbres, les égrins de pommiers français les plus gros dans trois variétés et le Malling XVI les plus gros dans deux variétés. Dans trois variétés, les arbres greffés sur Malling II sont plus grands que ceux greffés sur Malling XVI. Les poids notés à la taille indiquent la possibilité de réduire par la taille (1) les différences de croissance entre les arbres greffés sur les différents sujets et (2) la variabilité entre les arbres d'une certaine espèce. Les arbres greffés sur les égrins de pommiers français, d'abord uniformes au commencement de leur pousse dans le verger, sont maintenant tout aussi variables que les arbres greffés sur Malling XVI, qui étaient au début beaucoup moins uniformes. Les Greening de R.I. et Melba sont les deux seules variétés qui aient produit une quantité appréciable de fruits. Dans les deux variétés, les arbres greflés sur Malling II sont ceux qui ont produit le plus de fruits; les arbres greffés sur Malling I venaient ensuite. Dans les Greening de R.I., les arbres greffés sur Malling XVI ont mieux rapporté que ceux qui étaient greffés sur les égrins de pommiers français, mais cet ordre est interverti dans le cas de la variété Melba. Sur un côté du verger il y a quelques arbres des mêmes variétés greffées sur Malling IX. Ce sujet a provoqué différents degrés de rapetissement dans les différentes variétés, mais il a donné de meilleurs rendements par arbre qu'aucun des autres sujets et produit des fruits exceptionnellement bien colorés.

THE PRESENT STATUS OF GAS STORAGE RESEARCH WITH PARTICULAR REFERENCE TO STUDIES CONDUCTED IN GREAT BRITAIN AND PRELIMINARY TRIALS UNDERTAKEN AT THE CENTRAL EXPERIMENTAL FARM, CANADA

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INTRODUCTION

The development of gas storage of perishable products has made rapid strides since the Great War when food preservation was a matter of grave concern, with the result that there are at the present time five commercial gas storages for fruit in England having a total capacity of over 1,500 tons.

Although Berard (*2*) in 1821 was presented with a medal by the French Academy of Science for his paper on the lengthened storage life of fruit stored in atmospheres devoid of oxygen, there was very little interest displayed until the early part of this century. In 1907 Fulton (*10*) found that the bright appearance of strawberries was influenced by the tightness of the container as influencing the carbon dioxide concentration. Successful results were obtained by Gore and Fairchild (*12*) in 1911 using carbon dioxide in order to remove the astringency of Japanese persimmons. The effects of nitrogen and hydrogen were investigated by Hill (*13*) in 1913 upon ripe grapes and cherries which he found respired just as rapidly as in air for the first 36 hours of storage. On the other hand green peaches exhibited a depression on respiratory activity when subjected to similar treatment.

Bartholomew (*1*) and Stewart and Mix (*27*) have proved that lack of oxygen produces a toxic condition in the potato known as Black Heart, whilst excessive carbon dioxide concentration according to Shear, Stevens and Rudolph (*25*) causes spoilage and a bitter flavour with cranberries. Brooks and Cooley (*3, 4, 5*) studied carbon dioxide concentration in relation to temperature and noted that concentrated atmospheres of carbon dioxide at 30° C. produced a much more pungent flavour in apples than those stored in the same atmosphere at 10° C. and that the colour developed much more slowly under these treatments than those in air. They also showed that apples stored at 15° C. for five to seven weeks in atmospheres in excess of 5% carbon dioxide developed a pungent alcoholic flavour. Magness and Diehl (*20*) noted similar effects. Thatcher (*28*) studied the effect of carbon dioxide upon raspberries, blackberries and loganberries and was able to increase the storage life by four days and he suggested that internal breakdown of apples might be overcome by the retardation of enzymatic activity.

Oranges stored in excessive concentration of carbon dioxide were found by Onslow and Barker (*22*) to have a much greater alcoholic content than fruits stored in air.

The storage life of Fuerte Avocados was lengthened by one month by Overholser (*23*) who used 4 to 5% carbon dioxide and 4 to 5% oxygen at

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7.2° C. whilst 20 to 25% carbon dioxide prevented softening and failed to spoil the flavour when removed from storage.

Lettuces stored at low temperatures by Nelson (*21*) exhibited spotting which he attributes to the inability of the plant to absorb oxygen at such temperatures. The inhibition of mould and bacterial development during storage of bacon and pork at 32° F. in atmospheres of 100% carbon dioxide has been demonstrated by Callow (*8*). With both these products the flavour was not the least impaired. The importation of pork by this means from Canada to Great Britain has thus been rendered possible, as storage by this method after seventeen weeks produced no ill effects. Similarly anaerobic conditions by means of 100% carbon dioxide have been found by Coyne (*9*) to inhibit the growth of organisms which were isolated from the slime and intestines of fresh fish.

Sharp (*24*) reports that eggs may be kept longer in 3% carbon dioxide at freezing temperatures or in 10 to 12% at room temperature. The effect of the carbon dioxide is to maintain the original pH of the egg white which has a tendency toward alkalinity when stored in air and produces what is known as "watery white." Excessive carbon dioxide concentration will however cause turbidity in the white due to approaching the isoelectric point of protein. Thornton (*29*) using "Dry Ice" or solid carbon dioxide experimented with a great variety of plant material including flowers. Bud development of roses, dahlias and snapdragons varied with different carbon dioxide concentrations. It is interesting to note that he found the buds which were removed from cold storage in air lost their petals quickly whilst the buds stored in gas opened slowly with good colour and shape. He also states that the minimum period of treatment is 3 days and about 7 days as a maximum.

Brook *et al* (*7*) studied the effects of solid and gaseous carbon dioxide upon transit diseases of fruit. They state that in order to inhibit rots such as Botrytis, Rhizopus and Monilia it is necessary to use about a 25% concentration of carbon dioxide. Unfortunately however peaches, apricots, strawberries and raspberries exposed to such a concentration for 24 hours lose their aroma and the flavour is impaired, but lower concentration they maintain would be just as effective in holding the fruit as any method of precooling. This drawback is not so marked with plums, cherries, blackberries, blueberries, black raspberries, currants, pears, apples and oranges, furthermore a high degree of resistance was shown by peas, sweet corn, carrots and grapes. The last named fruit, grapes, did not shatter under such treatment. The treatment also was actually of more value in the retardation of softening than as a preventative against rot development. The authors also point out that the effects noted "were almost entirely due to the carbon dioxide gas, the refrigerating effect of the solid carbon dioxide being largely offset by a slower melting of the ice in the bunkers."

The rate of ventilation was found by Kidd and West (*17*) to greatly influence the rate of ripening of bananas as indicated by the following table.

Rate of ventilation for first 14 days			
Changes per day	15	60	240
Period (days) to ripen	14	16	21

In addition they point out that low percentages of either oxygen (1% to 2.5%) and carbon dioxide (1.5% to 10%) cause considerable retardation of ripening with bananas. The same authors and Trout (*18*) have investigated the keeping qualities of pears. Oxygen concentrations below 2% give marked retardation, a similar effect being produced by carbon dioxide concentration of 15 to 20%. Trout (*30*) also states that by excluding oxygen for a period he was able to extend the storage life of pears to the extent of 50% of the normal for any given temperature.

The Work of Dr. Kidd and Dr. West of the Food Investigation Board of Great Britain

The literature that has been reviewed demonstrates that the greater part of gas storage studies to date is composed of isolated experiments more or less demonstrating the effects of artificial atmospheres upon plant organs. The exhaustive studies of Kidd and West on apples are, however, worthy of special attention because they have now reached the point when definite recommendations as to the gas storage of certain varieties of apples are being adopted with success by commercial fruit growers. Their earlier work (*15*) was concerned with the effects of carbon dioxide and oxygen upon fruit which was stored in containers in which the carbon dioxide was allowed to accumulate, taking advantage of the fact that the rise in carbon dioxide concentration is proportional to the drop in oxygen concentration, the sum always remaining at approximately 21%. The varieties of apples used were Bramley's Seedlings, Chiver's Seedling, Stirling Castle and Lane's Prince Albert and the temperature ranged between 50° and 60° F.

Change in colour from green to yellow was noted and the difference between two varieties may be clearly seen from their results. Stirling Castle were yellow after 28 days and yellow-green after 114 days in an atmosphere containing 5 to 10% oxygen and 10 to 15% carbon dioxide, in the same atmosphere Lane's Prince Albert were quite green after 105 days and yellow stored in air for 35 days. Using a penetrometer or pressure guage they found that the rate of softening of tissue in Stirling Castle apples after 67 days in gas storage was given by a hardness value of 156 units against a value of 106 units with those stored in air. Air stored apples were found to be much sweeter than those stored in gas over the same period, similarly surface wax in the former group had developed to a greater extent.

The authors point out that the retarding effect has a definite limit beyond which such functional diseases as Brown Heart (*14*) and superficial scald make their appearance. The latter disorder was successfully controlled by oiled paper bearing out the findings of Brooks, Cooley and Fisher (*5*, *6*). They worked out the maximum efficiency of gas storage of the apples under experiment against those stored in air based upon, firstly, the mean storage life 50% wastage, and also the commercial storage life 10% wastage, the ratio on the former basis was 1 (air) : 1.64 (gas storage) and on the latter basis, 1 (air) : 2.17 (gas storage) using no temperature control.

Similar trials were then conducted on a semi-commercial scale in cooperation with Messrs. Chivers and Sons at Histon, Cambridge. The

eight ton commercial storage trial is of the most practical interest to us in that the investigators append the cash returns as shown in Table 1.

TABLE 1

Variety	Quantity stored	Wastage	Gross value at time of storage	Selling price	Date of sale
	lb.	%	£ s. d	£ s. d	
Bramley's Seedling	7,756	12 5	54 3 0	146 6 0	Mar. 1
Lane's Prince Albert	6,344	34	36 1 0	76 4 0	Feb. 16
Newton Wonder	600	14	4 15 0	11 8 0	Mar. 1
Lord Derby	582	17	3 10 0	13 0 0	Feb. 18
Stirling Castle	3,091	39	16 10 0	15 12 0	Mar. 7
Total	8¼ tons	24	114 19 0	262 10 0	

The authors observed that much less wastage occurred with apples on trays than those in boxes and that oiled paper controlled all scald. Furthermore small apples wasted less than large ones and fruit from grass plots kept better than that taken from cultivated plots. Fungal rotting was also considerably reduced by wrapping each apple.

In this experiment one difficulty was experienced which is of considerable importance to the Canadian grower. The seasonal temperatures may induce early ripening of fruit with subsequent high temperatures during the early storage period and this induces rapid fungal development. Naturally the higher the external temperature and the greater the volume of fruit the more serious is the problem of self heating of the fruit. Again it is noted that humidity under such conditions may become excessive, and they found that if the external temperature is higher than that in the store the water will be precipitated upon the apples, but when the temperature relationship is reversed the water would be deposited on the walls. With regulated ventilation there is also an accumulation of volatile products due to stagnant air conditions.

The greatest difficulty was in the construction of a really gas tight store and the leakage according to Glazebrooke and Griffiths (*11*) was not so much due to the diffusion of gas through the walls as to mass movement of the atmosphere through cracks. Many methods were tried out including aluminium paint, tar naphtha black applied to the concrete walls but the most satisfactory proved to be vaseline smeared over the internal surface and wallpaper soaked in vaseline placed over the layer of vaseline. Even with this method it was found difficult to maintain 10% carbon dioxide without any ventilation whatsoever. As will be seen later Kidd and West eventually used containers made of sheet iron for their work. In this connection the density of storage and the size of the chamber are important aspects (*26*). It was found that in unventilated holds the greater amount of fruit the greater the production of carbon dioxide while the rate of leakage is supposed to be the same with little carbon dioxide. Furthermore a large chamber will attain a higher concentration of carbon dioxide than a smaller one since it is stated "leakage is a surface effect and

gas production a volume effect and the surface/volume ratio of the chamber decreases as its size."

Gas Store and Cold Store.—The investigators state that in these early experiments gas stored fruit at 46.5° F. will keep as well as fruit stored in air at 34° F. but in the case of Bramley's Seedling apples the incidence of breakdown at 34° F. is a serious consideration. The comparative results indicate that mean storage temperatures are most effective with regulated ventilation. But if low temperatures are utilised less oxygen is required and vice versa. Table 2 illustrates the influence of gas mixtures upon the respiration of Bramley's Seedling apples. Later experiments show that fruit taken from gas store will stand up better than those removed from cold store.

TABLE 2

—	Const. temp.	Observed relative average rate of respiration	Inverse ratio	Relative limit of storage life (approx.)
Air store	46 5° F.	1 00	1 00	1.00
Gas store Carbon dioxide, 12% Oxygen, 9%	46.5° F.	0 54	1.85	1 80

Interesting observations were made upon the effect of carbon dioxide concentration in ships' holds carrying fruit (*26*). Accidental ventilation or leakage is increased tremendously by the battery system of refrigeration which entails forced air circulation, whilst there is no such ventilation with the grid system with a subsequent accumulation of carbon dioxide and development of Brown Heart in the apples. Kidd and West show that if there is sufficient accidental ventilation with the grid system the fruit in the centre of the hold will keep as well as fruit away from the centre because in the first instance there is gas storage with high temperatures and in the second instance cold storage in air.

It now remained for Kidd and West to unravel some of the complex issues connected with their previous work and this they accomplished by using one variety of apple, Bramley's Seedling, and storing the fruit in various gas concentrations at different temperatures (*16*). They eliminated the effects of humidity and volatile products by passing a slow stream of the gas through the cabinets which were adjusted to 90% relative humidity in all cases by bubbling through solutions of calcium chloride.

At 1° C. they found that decreased concentrations of oxygen and increased concentrations of carbon dioxide accelerated low temperature internal breakdown and that in all cases storage in all atmospheres at this temperature were less efficient than those stored in air, whereas at 5° C. all showed greater efficiency. The retardation of ripening was more pronounced by increases of carbon dioxide than with reduced oxygen concentration. For this particular variety they recommend storage at 5° C. in an atmosphere containing 10 to 15% carbon dioxide and about 10%

oxygen. By this method the storage life was increased half as long again as fruit stored in air at the same temperature.

The following striking statement is particularly worthy of note. "After thirty-four weeks storage samples of sound fruit were removed to air from atmospheres containing carbon dioxide and oxygen in the following percentage respectively, 5–5, 5–10, 5–15, 10–10 and 10–15 per cent. These apples were then quite green, firm and perfect in appearance and flavour. At the prevailing summer temperatures they remained in excellent condition for a further six weeks after which they were all used for culinary purposes."

The next variety to be tested was Lane's Prince Albert apples (*19*). Sheet iron storage cabinets were substituted for wooden cabinets as used in the previous trials. The flow of gas was also regulated so that at the lowest temperatures the rate was 10 cubic feet per day and at the highest temperatures 40 cubic feet per day. The authors in this work classify the criteria as to condition of fruit which is of distinct practical value.

(1) Ground colour.
(2) Firmness of flesh.
(3) Scald estimated as *(a)* percentage prevalence, *(b)* intensity as percentage of surface affected.
(4) Browning of flesh tissues *(a)* brown heart type, *(b)* breakdown type, *(c)* core flush type. These are measured as prevalence and intensity, the latter measured as percentage of median transverse section of the fruit.
(5) Fungal rots.
(6) Aroma, flavour and cooking quality.
(7) Wilting.

It was inadvertently found in these experiments that a short exposure to high concentrations of carbon dioxide, namely, 15%, produced a high percentage of breakdown and scald even as much as fruit exposed continuously.

The investigators state that although high concentrations of carbon dioxide are chiefly responsible for functional disorders oxygen exerts a partial influence. This effect is best seen where the amount of injury is greatest, namely, when 15% carbon dioxide is present. As another example of the keeping qualities of fruit after being subjected to artificial atmospheres Table 3 is included showing the condition of fruit removed to 60° F. after being stored at 39° F. for 206 days in various gas mixtures.

TABLE 3

Percentage		Percentage rots	Condition
Oxygen	Carbon dioxide		
2.5	5	25	Sweet, juicy, crisp, firm and ripe
5	5	50	Sweet, juicy, crisp, firm and ripe
10	10	50	Very soft, juicy, full ripe
Air		100	

Kidd and West again find with this variety of apple, Lane's Prince Albert Seedling, that gas storage at 1° C. is of no value and the conditions recommended for the variety is a temperature of 39° F. (4° C.) with an atmosphere containing 2 5% oxygen and 5% carbon dioxide. This treatment was found to be twice as effective as storage in air at 39° F. The authors conclude their investigations upon this particular variety of apples with some observations upon the influence of artificial atmospheres as affecting the chemical constituents of the apple. These are summarised as follows in their paper:—

(1) Increased carbon dioxide retards loss of carbohydrates, 5% gives greater retardation than 10 or 15%.

(2) Increased carbon dioxide appears to accelerate acid loss.

(3) Reducing the concentration of carbon dioxide has little effect upon loss of carbohydrates and acid loss.

(4) Increased carbon dioxide retards loss of alcohol insoluble material.

(5) Reducing oxygen concentration retards loss of alcohol insoluble material.

(6) Increased concentration of carbon dioxide accelerates the hydrolysis of cane sugar.

(7) Reducing the concentration of oxygen has little effect upon cane sugar hydrolysis.

GAS STORAGE STUDIES CONDUCTED AT THE CENTRAL EXPERIMENTAL FARM

In the summer of 1933 it was decided to test the efficiency of gas stored fruit. For this purpose a portable gas analysis apparatus (Orsat) was bought, accurate to 0 2%. A large wooden cabinet was specially constructed for gas tightness and contained four separate chambers with a capacity of 3 cubic feet. All the walls were composed of two layers of wood and oiled paper placed in between which was thoroughly coated with vaseline. The inside walls were then coated with parawax. The front of each chamber was removable and was bedded into a sunken opening which was covered with a thick layer of vaseline. After the chambers were filled the fronts were placed into position and screw clamped as tight as possible. Metal tubes were placed on each side of the four chambers for running in and drawing off the artificial atmospheres.

It was felt that more than one temperature should be used for the work and as the efficiency of the cabinet had not been gauged fully, 5 gallon lime sulphur cylinders were also utilised. The necessary aperture was made by cutting out the base, lining the walls with a wooden frame into which fitted a wooden lid and a rubber gasket was placed in between. The bung hole at the other end of the cylinder was closed with a rubber stopper through which two glass tubes were drawn for inlet and outlet purposes. No attempt was made in 1933 to make up artificial atmospheres of specific concentrations of the three component gases in air, instead various concentrations of nitrogen and carbon dioxide were used. In the first experiment (Trial 1) two varieties of strawberries were used, one box of each variety being placed in the cylinders which were placed under common storage conditions (60° F.). All fruit used in these investigations was

carefully selected for quality and was stored immediately after picking. Two cylinders were used, the initial internal atmospheres of each contained 100% and 92% nitrogen respectively and the object was to study the development of mould under such conditions.

Table 4 shows the subsequent gas analysis observation together with the percentage mould development at the end of five days.

TABLE 4.—PERCENTAGE GAS CONCENTRATION AT VARIOUS DATES AND MOULD DEVELOPMENT USING TWO VARIETIES OF STRAWBERRIES
(Commenced 30/6/33)

Cylinder	Gas	Per cent gas concentration			Per cent mould development, 4/7/33	
		30/6/33	3/7/33	4/7/33	Charles	Lilian
1	N_2	100	91 6	89 8	25 0	46 0
	CO_2	—	7 0	10 0		
	O_2	—	1 4	0 4		
2	N_2	92	91 0	89 8	11.3	22.5
	CO_2	—	9 2	10 0		
	O_2	..	0 8	0 2		
Check	Fruit stored in air				67.2	46.3

Whilst it is difficult to place much reliability on the data in Table 4 in view of the leakage it serves to demonstrate that in the variety Charles mould development was considerably checked. The difference between the results obtained from the cylinders cannot, however, be attributed to the concentration of nitrogen or of oxygen. It might be assumed that the respiratory activity of these fruits stored in 92% nitrogen was initially greater than those stored in 100% with a consequent increase in carbon dioxide concentration which would thus account for the lower percentage of moulds in Cylinder No. 2. This experiment demonstrated the difficulty of obtaining gas tight conditions as it was found impossible to include the results of a third cylinder.

The next experiment also using strawberries, variety Grace, was conducted with a view to ascertaining the effects of very high and low concentrations of carbon dioxide. The carbon dioxide as will be seen from Table 5 was reduced to a minimum by the use of soda lime.

From Trial 2 the findings of earlier workers (*7*, *10*, *29*) are corroborated, namely, that small fruits become very bitter when exposed to high concentrations of carbon dioxide but that such atmospheres maintain the original fresh appearance of strawberries. High nitrogen concentrations appear to have a deleterious influence upon the keeping qualities of the fruit as shown by the fruit stored in nitrogen plus soda lime. It would appear therefore that low concentrations of oxygen and an increase of carbon dioxide not exceeding 10% would be effective in lengthening the storage life of strawberries, nevertheless more critical experiments should be conducted to ascertain the optimum concentration of carbon dioxide. "Sweating" of small fruits is a serious factor in storage, and as may be

TABLE 5.—PERCENTAGE GAS CONCENTRATION AT VARIOUS DATES AND FINAL CONDITION OF STRAWBERRIES STORED IN CYLINDERS AT 48° C.
(Commenced 5/7/33)

Cylinder	Date	Percentage of gases			Condition of fruit 10/7/33
		CO_2	O_2	N_2	
1	5/7/34	82 0	1 0	17.0	Very bitter taste but appearance very good.
	6/7/34	34.0	11 4	54.6	
	7/7/34	16.8	12 65	70.55	
	8/7/34	11 0	15 8	73.2	
	10/7/34	7.9	16 8	75.3	
2	5/7/34	0 1	3.6	96 3	Soft and poor condition, wet.
	6/7/34	0 1	5 9	94 0	
	7/7/34	0 1	10.7	89 2	
	8/7/34	0.1	12 5	87.4	
	10/7/34	0.1	16 4	83.5	
3	4/7/34	0.95	2.2	96.85	Poor taste but better condition than fruit in No. 2 cylinder.
	6/7/34	4.1	0 2	95.7	
	7/7/34	4.75	0 35	94.9	
	8/7/34	6.0	1 4	92.6	
	10/7/34	8.5	0.2	91 3	
Check in air	Not so wet as fruit in No. 2 cylinder but in very poor condition.				

seen from Table 5 higher concentrations of carbon dioxide apparently influence this particular characteristic of senesence as the bright appearance is maintained.

In the next experiment, Trial 3, the wooden cabinet was utilized and various concentrations of carbon dioxide used. Two boxes of Clare strawberries and one box of Newman raspberries were placed in each of the four chambers which had a cubic capacity of 92 litres each. The fruit was subjected to the following treatments at 40° F.:—

No. 1 chamber contained air and was sealed.

No. 2 chamber flushed with 69 litres carbon dioxide.

No. 3 chamber flushed with 46 litres carbon dioxide.

No. 4 chamber flushed with 9 4 litres carbon dioxide.

The trials commenced on 12/7/33 and Table 6 shows the percentages of carbon dioxide and oxygen recorded during the period of treatment.

TABLE 6.—PERCENTAGES OF CARBON DIOXIDE AND OXYGEN IN STORAGE CABINET ON VARIOUS DATES CONTAINING RASPBERRIES AND STRAWBERRIES
TRIAL 3. (Commenced 12/7/33)

Chamber	Gas	13/7	14/7	15/7	16/7	17/7	18/7	19/7	20/7
1	CO_2	3.3	6 0	8 4	10.4	11 6	12.6	13.8	14.6
	O_2	15.3	18.6	17 0	16 4	15.4	15.0	13.2	13.0
2	CO_2	58.0	52 5	47.8	43.4	40 6	37 8	35.5	33.2
	O_2	7.0	9.5	9.7	11.6	10 9	11.4	11.7	11.8
3	CO_2	38.6	35 8	32 8	29 8	28.0	26 4	25.0	23.8
	O_2	12.7	12 9	12.8	13.2	13.5	13.4	13.6	13.6
4	CO_2	12.8	12.4	12.6	12.5	12.5	12.8	13.0	13.6
	O_2	17.0	18.0	16.8	16.0	15.9	15.6	15.2	14.6

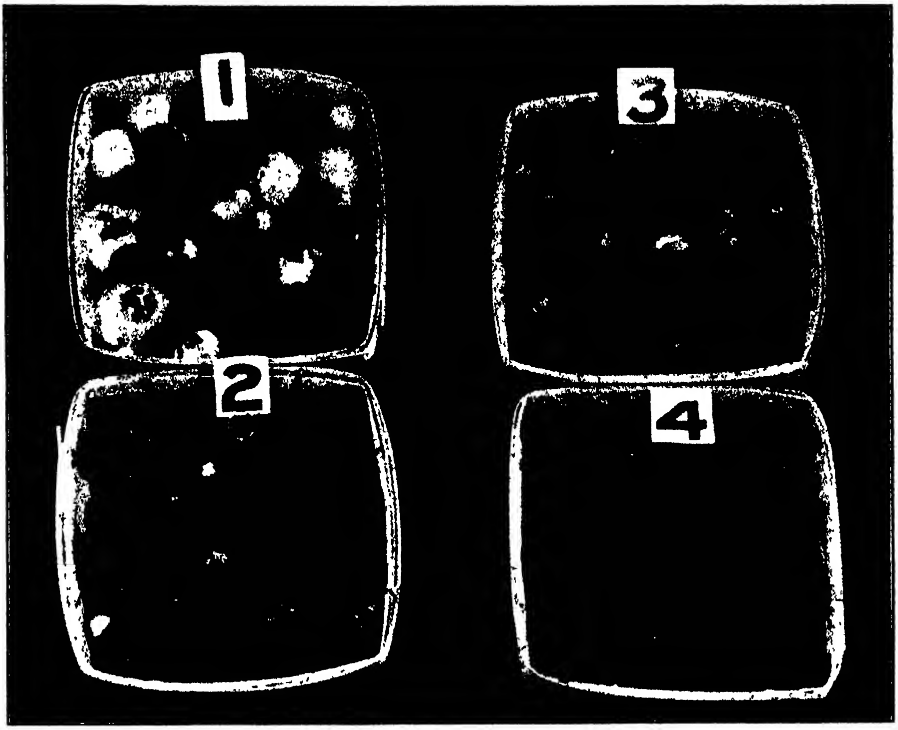

FIGURE 1. Fungal development on raspberries stored in various concentrations of carbon dioxide at 40° F. after 8 days. 1. Check—stored in air of cold storage chamber; 2. Air in gas tight chamber No. 1 (sealed); 3. 12% carbon dioxide in gas tight chamber No. 4; 4. 38% carbon dioxide in gas tight chamber No. 3.

The leakage from the cabinets was very pronounced and the flavour was not impaired by high concentration of carbon dioxide which is inexplicable in view of other results obtained elsewhere. The appearance of the berries in all series was very much the same presumably due to the relatively high concentrations of carbon dioxide used throughout. Nevertheless as the accompanying illustration (Figure 1) will clearly demonstrate, mould growth is inhibited by increased concentration of carbon dioxide. Figure 2 also illustrates the rise and fall of concentrations of carbon dioxide and oxygen respectively of the atmosphere in a closed chamber containing fruit. This illustrates the possibilities of using controlled ventilation for commercial storage.

The final test in 1933 was with Newman raspberries using both the cabinet and the cylinders, the former at 32° F. and the latter at 54° F. The fruit was stored in artificial atmospheres 21/7/33 until 1/8/33, two boxes in each cylinder and four in each chamber of the cabinet. Half the fruit was picked off a mulched area and the other half from a cultivated area but no specific differences in reaction were observed relative to cultural treatment. The object of this experiment was to try and correlate temper-

ature effects with atmospheric effects. The following percentages of carbon dioxide and nitrogen were used:—

54° F.	No. 1 cylinder	50% dioxide
	No. 2 cylinder	75% dioxide
	No. 3 cylinder	100% dioxide
	Check in air	

32° F.	No. 1 chamber	100% nitrogen
	No. 2 chamber	50% carbon dioxide
	No. 3 chamber	75% carbon dioxide
	No. 4 chamber	100% carbon dioxide
	Check in air	

The high concentration of carbon dioxide caused the flavour to become very bitter and also the fruit colour changed from red to light pink. The nitrogen treatment produced no ill effects; apart from loss of flavour the fruit kept firm and dry in contrast to strawberries kept under similar condition. It will be remembered that with strawberries the fruit kept dry in high concentrations of carbon dioxide; furthermore strawberries store better at higher temperatures than raspberries which indicates that entirely different storage conditions are necessary for each of these fruits. Again the mould growth was controlled by carbon dioxide at high temperatures; furthermore the check at 32° F. proved to be the best of the series in all respects.

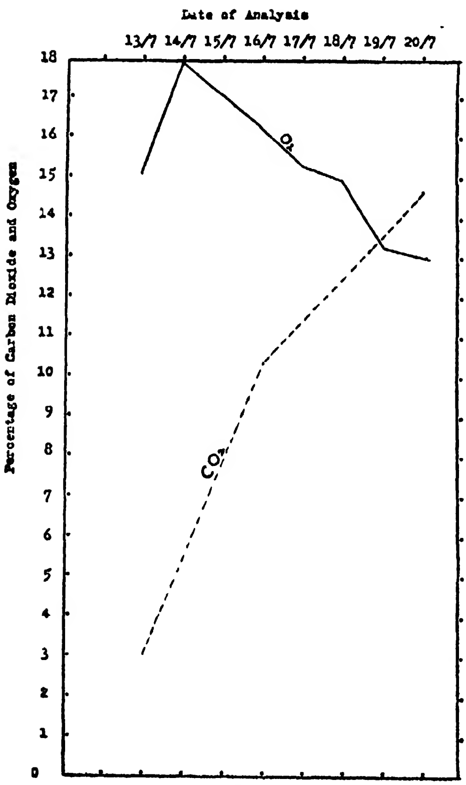

FIGURE 2. Raspberries stored in ordinary atmosphere (Trial 3). Percentage of carbon dioxide and oxygen in gas tight chamber.

It was decided in 1934 to equip so that specific mixtures of carbon dioxide, oxygen and nitrogen could be made up. Accordingly cylinders were obtained and the mixtures placed in them by adding each gas under pressure. Only one experiment was conducted with small fruits. It was found that large containers were unsatisfactory because of the large quantities of gas mixture required to keep the atmosphere in the proportion required. An attempt was made to draw a partial vacuum in the wax-lined cabinet but this procedure only increased the number of leaks. This was also tried on tin cans but they collapsed. The only alternative

therefore was to flush the container with the mixture, which as stated before is wasteful. Thus it was decided that for small fruits 1 litre Erlenmeyer flasks could be used. These were fitted up with two-way stoppers, and approximately twenty-five berries, Variety 21-0745, placed in each, the following mixtures were used at three temperatures, 32° F., 36° F. and 40° F.

(1) 5% CO_2—15% O_2
(2) 10% CO_2—10% O_2
(3) 15% CO_2— 5% O_2
(4) 20% CO_2— 0% O_2

It will be seen from Table 7 that a much more uniform gas content was maintained than in any of the previous attempts when repeated flushes with the mixture were carried out.

TABLE 7.—GAS ANALYSIS OF SERIES AT 36° F. RASPBERRIES STORED IN ARTIFICIAL ATMOSPHERES

No. of mixture	Gas	Original mixture 17/7/34	18/7	Flushed 20/7	21/7	23/7	Flushed 25/7	Flushed 28/7	30/7
1	CO_2	5 0	6 3	5 2	5 2	7 0	8.4	10 2	9.7
	O_2	12 6	12 1	12 6	11.8	10.8	9 0	8 2	8 4
2	CO_2	10 4	11 8	10 5	10 6	12 4	12 6	*	14.3
	O_2	9 6	8 4	9.1	9 4	7 8	6 5		6 9
3	CO_2	15 0	14 2	15 1	15.2	14.8	14.0	15.4	15.6
	O_2	4.4	5 8	4.2	4 2	5 6	5 3	6 0	4 5
4	CO_2	20 0	20 1	20 6	20 6	21 4	*	20 05	20 5
	O_2	1 9	1 1	1 7	1 6	1 4		1.2	1 5

*Mixture exhausted.

The berries stored at 32° F. in an atmosphere containing 5% carbon dioxide and 15% oxygen kept for thirteen days in good condition whilst the second best treatment was 10% carbon dioxide and 10% oxygen at the same temperature. In this latter treatment the only setback was a slightly abnormal flavour.

The control of moulds is efficient at 32° F. in ordinary atmospheres but it was observed that they developed freely at the higher temperatures, namely, 36° F. and 40° F. Furthermore repression of such mould development by the artificial atmospheres used in this experiment showed that only concentrations of 15% and over of carbon dioxide were effective. Unfortunately at all temperatures used abnormal flavours became evident with a carbon dioxide concentration of 10%. It may therefore be concluded that with temperatures of 36° F. and above no specific concentrations of carbon dioxide are of value in lengthening the storage life, the limiting factors being mould development and bitterness of flavour.

It has also been shown in previous trials that atmospheres almost devoid of oxygen are not instrumental in controlling moulds on strawberries and that this same condition is productive of poor flavour with raspberries. It may thus be inferred that very low oxygen concentrations

and high concentrations of carbon dioxide are undesirable in regard to flavour.

These tests have shown that at 32° F. a concentration of 5% carbon dioxide produces no ill effects but that 10% causes slight loss of flavour. It will be observed however in Table 7 that toward the end of the test the carbon dioxide concentration had risen from 10 to 14%. Such an increase it may be suggested would bring about the slight abnormal flavours noted. In view of the observed decrease in "sweating" and maintenance of the bright appearance of raspberries as associated with high carbon dioxide concentrations it would appear that fruit stored in a maximum concentration of this gas relative to flavour, would be under optimum conditions. Such preliminary trials indicate that carbon dioxide in concentrations between 5 and 10% and corresponding percentages of oxygen would be suitable for the storage of small fruits. Further critical experiments should be conducted in order that more specific gas concentrations might be determined.

SUMMARY AND CONCLUSIONS

The defects and difficulties in connection with some gas storage trials have been reported and discussed and it appears that glass, galvanized iron or metal containers are the only efficient materials for "gas tight" storage.

Sufficiently accurate gas mixtures may be made up by passing the component gases into a stock cylinder under pressure. Great difficulty was experienced in maintaining the mixture over fruit under stagnant conditions in large containers and heavy wastage of the gas mixture was entailed by flushing. The only alternative under such conditions would be to pass a slow stream of the artificial atmosphere continuously over the fruit. Regulated ventilation may be used to control the carbon dioxide concentration over stored fruit.

Trials with small fruits in artificial atmospheres showed that pure nitrogen had a very deleterious effect upon strawberries at 54° F. Raspberries lost their flavour in such an atmosphere at 32° F. but otherwise remained in good condition. Very low concentrations of oxygen produce a deleterious effect upon the flavours of both strawberries and raspberries. Mould development may be controlled by storing these fruits at 32° or in concentrations of carbon dioxide of 15% and above.

High concentrations of carbon dioxide were found to decrease "sweating," softening, mould growth and to maintain the bright appearance of strawberries and raspberries. Nevertheless both fruits took on bitter flavours under such conditions and raspberries tended to turn pink in colour. With raspberries in order to maintain original flavours 10% carbon dioxide is the maximum storage concentration and best results were obtained with these fruits when stored at 32° F. in atmospheres containing 5% carbon dioxide.

ACKNOWLEDGMENT

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LITERATURE CITED

1. Bartholomew, E. T. A pathological and physiological study of the black heart of potato tubers. Centble. Bakt (etc.) (11) *43* : 609-639 illus. 1915.
2. Berard, M. Du memoire sur la maturation des fruits. Ann. Chem. et Phys. (2) *16* : 225-251. 1821.
3. Brooks, C., J. S. Cooley. Effect of temperature, aeration and humidity on Jonathan Spot and scald of apples in storage. Jour. Agr. Research *11* : 287-318 illus. 1917.
4. ——— and D. F. Fisher. Apple scald. Jour. Agr. Research *16* : 195-217 illus. 1919.
5. ———. Nature and control of apple scald. Jour. Agr. Research *17* : 211. 1919.
6. ———. Nature and control of apple scald. Jour. Agr. Research *18* : 211-240 illus. 1919.
7. ———. Effect of solid and gaseous carbon dioxide upon transit diseases of certain fruits and vegetables. U.S.D.A. Tech. Bul. 318. 1932.
8. Callow, E. H. Gas storage (meat) Rept. Food Invest. Board (G.B.) 112. 1932.
9. Coyne, F. P. The effect of carbon dioxide on bacterial growth with special reference to the preservation of fish. Rept. Food Invest. Board (G.B.) 194-196. 1932.
10. Fulton, S. H. The cold storage of small fruits. U.S.D.A. Bur. of Plant. Indus. Bul. 108, 28 p. illus. 1907.
11. Glazebrook, Sir R. and Griffiths, E. The scientific study of heat insulating materials. Proc. 4th Internal. Congress Refrig. *1* : 335. 1924.
12. Gore, H. C. and Fairchild, D. Experiments on the processing of persimmons to render them non-astringent. U.S D A. Bur. Chem. Bul. 141, 31 p. illus. 1911.
13. Hill, G. R. Respiration of fruits and growing plant tissues in certain gases with reference to ventilation and fruit storage. N.Y. Cornell Agric. Exp. Sta. Bul. 330, p. 377-408. 1913.
14. Kidd, F. and West, C. Brown heart - a functional disease of apples and pears. Food Invest. Board (G.B.) Spec. Rept. 12. 1923.
15. ———. Gas storage of fruit. Food Invest. Board (G.B.) Spec. Rept. No. 30. 1927.
16. ———. Gas storage of fruits, II Optimum temperatures and atmospheres. Jour. of Pom. and Hort. Sci. *8* : 67-77. 1930.
17. ———. The influence of carbon dioxide, oxygen and rate of ventilation upon the storage, ripening and respiration of bananas. Rept. Food Invest. Board (G.B.) 100-103. 1931.
18. ———, and S. A. Trout. Gas storage of pears. Rept. Food Invest. Board (G.B.) 92-99. 1931.
19. ——— Gas storage of fruit, III. Lane's Prince Albert Apples. Jour. of Pom. and Hort. Sci. *9* : 149-170. 1933.
20. Magness, J. R. and Diehl, H. C. Physiological studies on apples in storage. Jour. Agr. Research *27* : 1-38. 1924.
21. Nelson, R Storage and transportational diseases of vegetables due to suboxidation. Mich. Agric. Exp. Sta. Tech. Bul. 81, p. 38. 1926.
22. Onslow, M. and Barker, J. The alcohol content of oranges and its diagnostic value. Rept. Food Invest. Board (G.B) : 35. 1927.
23. Overholser, E. L. Some limitations of gas storage of fruits. Ice and Refrigeration *74* : 551-552. 1928.
24. Sharp, P. F. The pH of the white as an important factor influencing the keeping of quality of hen's eggs. Science (N.S.) *58* : 278. 1927.
25. Shear, C. L., W. E. Stevens and B. A. Rudolph. Observations on the spoilage of cranberries due to lack of proper ventilation. Mass. State Agric. Exp. Sta. Bul. *180* : 235-238. 1917.
26. Smith, A. J. The gas content and ventilation of refrigerated holds carrying apples. Food Invest. Board (G.B.) Spec. Rept. No. 21. 1925.
27. Stewart, F. C. and A. J. Mix. Blackheart and the aeration of potatoes in storage. N.Y. Geneva Agric. Exp. Sta. Bul. *436* : 321-362. 1917.
28. Thatcher, R. W. Enzymes of apples and their relation to the ripening process. Jour. Agr. Research *5* : 103-116. 1915.
29. Thornton, W. C. The effect of carbon dioxide on fruits and vegetables in storage. Contrib. Boyce Thompson Inst. *3* : 2; 219-244. 1931.
30. Trout, S. A. Experiments on the storage of pears in artificial atmospheres. Jour. Pom. and Hort. Sci. *8* : 78-91. 1930.

Résumé

La situation actuelle des recherches sur la conservation au gaz avec mention spéciale des études conduites en Grande-Bretagne et des essais préliminaires entrepris à la Ferme expérimentale centrale, Ottawa, Canada. C. A. Eaves, station expérimentale fédérale, Kentville, N.-E.

Les difficultés rencontrées au cours de certains essais de conservation au gaz sont signalés dans cet article et il appert que les contenants de verre, de tôle ou de métal sont les seuls matériaux qui puissent retenir le gaz. On peut obtenir des mélanges de gaz suffisamment exacts en faisant passer sous pression les gaz constituants dans un cylindre. Dans des conditions stagnantes, et dans de grands contenants, on a éprouvé de grandes difficultés à maintenir le mélange sur les fruits, et l'introduction d'une masse de gaz a entraîné de grosses pertes du mélange. La seule alternative dans ces conditions serait de faire passer un courant lent et continu de l'atmosphère artificielle sur les fruits. Une ventilation contrôlée peut être employée pour régler la concentration du gaz carbonique sur les fruits entreposés. Les essais effectués sur de petits fruits, dans des atmosphères artificielles, ont fait voir que l'azote pur exerce un effet très délétère sur les fraises à 54 degrés F. Lorsque l'atmosphère est à 32 degrés F., les framboises perdent leur goût, mais elles restent en bon état sous d'autres rapports. Des concentrations très faibles d'oxygène produisent un effet délétère sur le goût des fraises et des framboises. On peut enrayer le développement des moisissures en conservant ces fruits à 32° ou dans des concentrations de gaz carbonique non inférieures à 15%. On a constaté que de fortes concentrations de gaz carbonique diminuent le ressuage, l'amollissement, la croissance des moisissures et conservent l'aspect brillant des fraises et des framboises. Cependant, ces deux sortes de fruits ont contracté un goût amer dans ces conditions et les framboises avaient une tendance à prendre une couleur rose. Sur les framboises la concentration maximum de gaz carbonique qui permet de maintenir le goût est de 10% et on a obtenu les meilleurs résultats avec ces fruits lorsqu'ils étaient entreposés à 32°F., dans des atmosphères contenant 5% d'acide carbonique.

CIDER AS A FRUIT PRODUCT[1]

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The surplus production of apples in this country in the past few years has created a definite problem. If the production of apple cider would absorb a part of this surplus, the advantage would be quickly felt in higher prices for apples and the profitable sale of culls and windfalls to the fruit products plants. The difficulty producers have in selling their apples on a glutted market, demands a reduction of surplus apples. This might be accomplished by reducing production, but better still by utilising the surplus in producing other products.

Possibilities of Using Surplus for Cider

The advantages of having a market specifically demanding culls and windfalls becomes obvious in that the grower can rely on disposing of this quality of fruit without having to dump it on the general market in competition with his graded stock. The fact that the cost of handling would be cheap is not to be overlooked, since picking, in most cases, could be reduced to shaking the fruit from the trees. No elaborate grading or packing would be necessary; the same barrels could be used repeatedly for packing and shipping. Furthermore the cider factory would naturally be situated near the apple growing district so that shipping charges would be reduced to a minimum. Such things as insurance, sales agents, storing, etc., would not need to be considered.

Many of the fruit products plants in Nova Scotia have been buying culls and windfalls for as little as twenty to thirty cents a barrel. If used for cider a barrel of apples will yield eight to ten gallons of juice. If the juice is processed into cider, bottled and retailed at the same price as beer, namely fifteen cents a small bottle, then our barrel of apples will have reached a retail value of approximately $15. The possibilities here become obvious at once. A demand for culls and windfalls would raise the price to the grower and still leave plenty of opportunity for the profitable manufacture of cider, especially so since the cider maker hasn't the same overhead as the canner who must consider the cost of individual handling, coring, peeling and trimming for each apple. Furthermore, apples being delivered to the cider plant need not be segregated into varieties as is the case in the canning plant. The varieties can be more or less freely mixed when pressed without doing harm to the cider for, as will be pointed out later, judicious blending and processing can be made to bring up the flavour and quality appreciably.

While dealing with these possibilities of using surplus apples for cider the following information will prove interesting. The distribution of the Nova Scotia commercial apple crop from 1928 to 1932 shows a substantial amount going to fruit products factories. Of the apples processed, cider accounted for approximately 7% in 1928; 8.5% in 1929; 55% in 1930; 42% in 1931; and 58% in 1932. If this increase in the use of apples for

[1] Paper presented before the Horticultural Group at the C.S T A. Convention at Macdonald College, June 27, 1934.
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cider manufacture continues and spreads to the other apple-growing provinces the cider industry will assume considerable importance not only to consumers but to the growers.

Historical

Cider was made in early times and was quite a common beverage for —"The ordinary course among the lower class was to breakfast and sup with toast and cider through the whole of lent." Of course the cider was a rough drink often made from crabs and wild apples. Towards the end of the eighteenth century when continental wars prevented the importation of wines, cider production became an object of national importance and a patriotic duty. As a result great English cider orchards of the southwest came into being.

There were two kinds of cider made at this time, one of a superior quality made from the first brew and served in the best establishments; the other was termed "ciderkin" a weaker cider made by the addition of water to the "must" and was given to the men at work in the fields. With the application of a tax on the orchards and their produce many orchards were uprooted or allowed to decline. The cessation of the Napoleonic war further aggravated the situation since foreign wines were again able to compete with the home product. As a result the quality of cider greatly deteriorated.

Fortunately, the pendulum has swung the other way. Cider has become a high-quality beverage and a favourite drink with people of all classes. The production shows a steady increase until now the annual consumption of cider in England is estimated at about two gallons per capita. Due to the importance cider has achieved in England, definite cider varieties have been developed and grouped into different classes. Kingston Black, Tom Putt and Foxwhelp are among the best known of the sharp class. Morgan Sweet, Improved Pound and Sweet Alford belong to the sweet class. Then Cherry, White Norman, Chissel Jersey, Knotted Kernel and Dabinett are included in the bitter sweet class. However, English cider is not made exclusively from such varieties. Cull apples are very largely used being blended with juices of the above mentioned varieties.

Possibilities of Utilising Common Dessert and Cooking Apples for Cider in Canada

One might naturally think, since some of the prominent varieties of apples used exclusively for cider making in England have been pointed out, that we should find it necessary to develop special varieties for cider making in Canada. It is not felt that this is necessary; it is possible to use the ordinary run of orchard culls and surplus apples. True, such a mixture may be unsatisfactory as such, but, we have found that some varieties of crab-apples give juices which are splendid for blending. We have used such varieties as Martha, Quaker Beauty, Lymans Prolific and Burgess with satisfaction. Even the fruit of some ornamental crabs were excellent for this purpose.

Another likely reason for not cultivating varieties of cider apples such as those grown in Europe is the possible difference in national tastes. The

popular ginger-ales in Great Britain do not meet with favour in this country and similarly the type of cider which may prove most popular here need not be the same as that of England, France or Germany.

Some Methods of Cider Making

There are different methods of making cider which are briefly described, and some attention is given to the method used in the fruit products laboratory at Ottawa.

Vat Fermentation

This method is usually employed to make cider for home consumption or producing bulk cider. The fundamentals consist of pressing the fruit, filtering the juice, fermenting in vat either by inoculation or with natural yeast and racking it off into a clean barrel when it has reached the correct stage for drinking. There are various elaborations which the maker may develop for altering the flavour and quality to his own taste.

Bottle Fermentation

Bottle fermentation is the method most commonly used in European countries for making bottled cider and especially champagne cider. The essential steps are pressing the fruit, blending the juices and storing in large fermenting vats. The rate of fermentation, as denoted by the specific gravity, is carefully watched. When the specific gravity has dropped to about 1 030, which is about five points above the final gravity desired (namely 1 025), the cider is racked off, filtered and bottled. The bottles are then placed in a cool room while the small amount of yeast in each bottle slowly carries on fermentation and charges the cider with carbon dioxide. In some cases the sediment is left in the bottle or it may be removed by disgorging or by chilling the cider and pouring the clear cider into fresh bottles. Each producer of course has his own especial method of blending and processing.

Cold Pack Method - Closed Cuvee Process

In the fruit products laboratory at Ottawa we use the Closed Cuvee Process and believe that it holds the best possibilities for cider making in this country. No hard and fast routine is laid down but a fairly regular procedure is as follows.

Pressing.—The fresh fruit is dumped into a large tank of water which is kept agitated. The clean apples are then paddled onto a pulley which conveys them to the press. They are crushed into a pomace which is dropped in layers about one inch thick onto press-cloths. The cloths are folded over completely enclosing the pomace. A series of these layers of pomace (usually six) is built up one on top of the other and each separated by an open lattice press-board. Such a series, or cheese, as it is termed, is placed under the hydraulic press for about twelve minutes.

Storage.—The expressed juice may be clarified by passing through a high-speed centrifuge, then through either an asbestos pulp prefilter or a plate filter using diatomaceous earth as a filter-aid. The delivered juice is clear and free from all visible suspensions. A further filtration through Seitz E. K. plates completely sterilizes the juice allowing it to flow into a sterile vat where it may be held indefinitely in a sterile condition.

If sterilization is unnecessary the juice is pumped into vats directly from the press and fermentation permitted to proceed until hard cider is

formed. Hard cider can be kept wholesome for months provided the vats are kept clean and completely filled so that no air can enter.

Blending.—When preparing a batch of cider for bottling the first step is to make up the desired blend. Measured quantities of the various juices are thoroughly mixed together until the desired appearance, flavour and body are secured. After determining the difference between the alcoholic content of the blend and that desired sufficient applejuice concentrate is added to make up the difference and give a finished product of about 1.025 specific gravity.

Correctives and Clarifiers.—After making up the blend it may be found that the acidity is too high. This can readily be overcome by adding sufficient calcium carbonate to reduce the aciditv to between 0.45% and 0.5% malic acid, which is the normal acidity for bottled cider.

It may often be found, too, that the colour is far too deep and dark so that some clarification and colour reduction are necessary. There are several ways of doing this, but the most common and satisfactory is by fining which is accomplished by adding definite quantities of tannin and gelatine in separate solutions. Usually stock solutions of each are made up and definite amounts of each added to separate samples of cider to determine which proportions of tannin and gelatine give the best results.

Immediately on adding the fining materials a sludge forms which gradually settles to the bottom carrying with it most of the suspended material and a large amount of colouring matter. In a few hours a light transparent cider remains which is easily drained off.

Final Clarification and Sterilization.—The blended cider is next passed through the centrifuge to remove most of the sediment resulting from fining. Any sediment remaining is removed by a prefiltration either through asbestos pulp or a filter aid such as diatomaceous earth.

Sterilization is accomplished as previously described, namely through Seitz-filter containing asbestos sterilizing discs after sterilizing the filter with live steam. The sterilized cider is placed in a sterile vat to undergo fermentation.

Inoculation and Fermentation.—About one week before making up the blend a giant yeast culture is started by inoculating a small flask of sterile cider or sugar solution either from an agar slope or stock solution culture. When fermentation is proceeding rapidly the contents of the flask are added to a demijohn containing about 5 gallons of sterile cider. Then when fermentation becomes rapid (in about three or four days) the whole culture is added to the prepared blend. Fermentation usually proceeds rapidly, and a constant check is maintained by specific gravity readings.

Fermentation Tank.—When the specific gravity has dropped to about 1.035 the cider is pumped into a large glass-lined, steel pressure tank. Here, fermentation continues until the specific gravity has dropped to the required point, usually about 1.025 and since the tank is completely closed the carbon dioxide evolved builds up a pressure usually to about 60–70 pounds per sq. in. Occasionally fermentation may slow down while the cider is in the fermenting tank in which case it is often possible to hasten it by placing a small auxiliary heater under the tank to hold temperature at 75°–85° F.

Brine Cooling Tank.—When the proper specific gravity has been reached the cider is filtered through the Seitz prefilter into the cooling

tank which is a glass-lined, steel tank exactly the same as the fermenting tank but with an outer jacket. However, before transferring the cider a pipe-line is connected to the top valves of each tank and the compressed CO_2 in the fermenting tank passes through until the pressure in the two tanks is the same. Then the cider is pumped through the filter under counter pressure. The filtration clarifies the cider and removes most of the yeast sediment. The cooling tank is then charged with CO_2 to bring the pressure up to 50–60 pounds per sq. in. and cold brine is pumped through the outer jacket to hold the cider at about 28° F. When the cider is thoroughly cooled it is circulated by means of a juice pump to enable a greater absorption of carbon dioxide.

Counter-Pressure Bottling.—Usually the cider is ready for bottling after two days in the cooling tank. Hence the Seitz filter is previously built up with asbestos sterilizing discs and connected with the bottling machine. This line-up is sterilized with live steam at 10 lbs. for 45 minutes and cooled by passing cold water through the set-up. The filter is then connected to the bottom valve of the tank and the gas outlet on the bottler is joined through an air filter to the top valve. The valves are then opened with alternate differentials of 10 pounds pressure per sq. in. until the pressure has become equalized throughout. The cider is pumped through the filter into the reservoir of the bottling machine from which the bottles are filled. Each spout on the bottling machine, which is the champagne type, has a double valve which when partly opened fills the bottles with compressed CO_2 and when fully opened permits the cider to enter the bottles under counter-pressure thus preventing foaming.

Naturally, as the cider is bottled the pressure in the line-up would drop. To offset this a cylinder of compressed CO_2 is connected in the gas line with a pressure-control valve attached to keep the pressure constant during the bottling operation.

As the bottles are filled they are placed on a revolving counter-pressure table which holds the open ends tight against a rubber plug to allow any foaming to subside without losing the contents of the bottles. The bottles are then removed and capped or corked ready for storage.

Similar Methods

Other methods are used which differ somewhat from the Closed Cuvee Process. One of these is to do away with the fermenting tank and carbonate artificially while bottling. However, the natural aroma and bouquet retained by natural carbonation is often lost if artificial carbonation is resorted to.

Pasteurization has been tried to obviate the use of the Seitz sterilizing filter but many people complain that cider pasteurized in bottles has a cooked flavour.

Storage

Bottled cider should be stored in a cool, airy room. A temperature of about 40° F. is satisfactory since the greatest flavour is experienced when served at this temperature. Also, the bottles should be stored on their sides thus keeping the stoppers wet and preventing the escape of CO_2 through dry stoppers.

Controlled Variation of Cider

One of the advantages which cider has over other beverages is that it can be made to suit several tastes. For those who cannot or will not drink an alcoholic beverage a sweet cider can be made either still or carbonated.

This is a very popular drink throughout eastern Canada and the United States.

Then for those who prefer some stimulant in their beverage a medium cider containing up to 7% alcohol is suitable. Where an even stronger and finer beverage is wished a champagne cider is available containing 10 to 12% of alcohol. This ability to vary the alcoholic content of the cider to suit varying tastes should be a strong attraction to the producer.

Cider Troubles

Lest any should think that cider-making is simple and easy to master, some of the difficulties involved should be mentioned. Trouble may suddenly appear without apparent reason, but since there usually is a reason for everything, we try to find what it is and how to control or avoid the trouble.

(a) Arrested Fermentation.—A batch of cider inoculated with a vigorous yeast culture may not ferment, or fermentation may proceed for a short time then gradually stop. Sometimes, as suggested before, it may be due to insufficient heat since most yeasts have an optimum temperature of 75° to 85° F.

Another reason sometimes encountered is insufficient yeast food. During processing, centrifuging and filtering remove large amounts of suspended material and fining carries down so much food that when inoculated the yeast cells may be starved. In such cases the addition of small amounts of such compounds as ammonium sulphate, ammonium phosphate or potassium phosphate will enable fermentation to proceed.

(b) Blackening and Greening.—Another trouble sometimes encountered is a complete blackening of the cider, usually on exposure to air. This is usually accompanied by a decrease in the acidity. There may be several reasons for this trouble; one is that an acid-destroying bacteria is responsible. We have isolated several organisms one of which apparently causes some darkening but does not alter the acidity. Another possible cause is an excess of calcium, perhaps resulting from reduction of acidity with calcium carbonate, but up to the present we have no definite results to prove this point.

Metallic contamination is a likely possibility. Iron does turn cider black, evidently due to the formation of iron tannates. However, it has been found that iron will also gradually blacken a solution of malic acid which is the chief acid in apples. Usually, where blackening is accompanied with a decreased acidity the addition of a fruit acid such as malic, citric or tartaric acid will restore the cider to its normal colour.

The appearance of a green colour in the cider is occasionally encountered and is probably due to copper contamination. Thus the importance of avoiding metallic contamination cannot be stressed too much. Apart from the effect on colour, such contamination will stop fermentation. The cure for such a trouble is one of prevention. All metal parts with which the cider comes in contact should be silver plated or tinned.

Sedimentation.—Occasionally cider which has been bottled sparkling clear may develop a cloudiness or throw a sediment. The presence of pectin is sometimes responsible evidently becoming insoluble and settling out.

Residual chlorine remaining in the bottles after sterilizing with chlorine solution will cause sedimentation. As little as 0.6 ppm. of chlorine has been found to cause the formation of sediment.

Casse.—The appearance of "casse" or "break" in bottled cider may render the appearance slightly unattractive. The "casse" usually takes the form of breaking down of some constituents resulting in a peculiar sediment. A good preventive is the addition of sulphur dioxide which inhibits the action of peroxidase, the enzyme which is apparently responsible.

Lack of Sterility.—If the cider is not sterile in the bottle, trouble is likely to develop. True, moulds will not grow in the highly carbonated liquid. But yeasts and certain forms of bacteria will cause a sedimentation which although not objectionable in Europe is nevertheless to be avoided here.

The bottles should receive a thorough washing in hot caustic soda, full rinsing in clear water and a complete rinsing with sodium hypochlorite testing about 1000 ppm. of free chlorine; this will give sterility. To avoid the sedimentation due to chlorine, experiments are being carried out for the removal of residual chlorine from the bottles without endangering sterility.

SUMMARY

The possibility of converting low grade apples into cider is discussed showing how the grower will benefit not only from the sale of such apples but also by removing them from competition with higher quality fruit. After showing briefly how cider production has developed in England and the development of cider varieties, the author points out that such varieties need not be developed here because many of our common apples when blended properly with juices of some crabapple varieties make an excellently flavoured beverage. A short description of various methods of cider making is given with a more detailed account of the Closed Cuvee Process as developed at the Fruit Products Laboratory, Central Experimental Farm, Ottawa. In conclusion the author discusses such troubles as arrested fermentation, blackening and greening, sedimentation, "casse" and lack of sterility.

Résumé

Le cidre, un produit des fruits. Wm. Ferguson, Ferme expérimentale centrale, Ottawa, Ont.

L'auteur traite de la possibilité de convertir en cidre des pommes de qualité inférieure. Il montre qu'il y a avantage pour le producteur à utiliser les pommes de cette façon, plutôt que d'essayer de les vendre en concurrence avec des fruits de qualité supérieure. Après avoir relaté sommairement comment la production du cidre s'est développée en Angleterre et comment les variétés à cidre ont été créées, l'auteur fait remarquer qu'il serait inutile de développer ici des variétés de ce genre parce qu'un grand nombre de nos pommes communes, mélangées dans la proportion voulue avec le jus de quelques variétés de pommettes, font un breuvage à goût exquis. Il donne une description sommaire des différents procédés de fabrication de cidre avec un compte rendu détaillé du procédé de "cuve close", développé au laboratoire des produits fruitiers, Ferme expérimentale centrale, Ottawa. En terminant, l'auteur traite de certains désordres comme l'arrêt de la fermentation, le noircissement et le verdissement, la sédimentation, la "casse" et le manque de stérilité.

TWO NEW METHODS OF DISTINGUISHING CERTAIN CANADIAN WHEATS

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For some time, it has been the aim of the plant breeder and plant systematist to obtain additional methods of identifying the numerous commonly grown wheat varieties. The positive identification of the Hard Red Spring Wheats of the same species by means of the kernel characters has not always been completely satisfactory.

The need of such a verification system is quite obvious in both the seed and grain trade. Those who have to distinguish between such varieties as Marquis, Reward and Garnet find the present cultural methods take either too long or do not provide a satisfactory clear cut identification.

Harrington (*4*) published an article on "Seedling Identification of Some Canadian Spring Wheats" with special emphasis on the Marquis, Reward and Garnet varieties. The differential seedling hairiness of Reward and Marquis wheats one day after emergence led to the successful separation of the two varieties. The test required about nine days to complete the identification of the varieties.

More recently, Friedberg (*2, 3*) published detailed articles on the classification of wheats according to their colour reaction to phenol. The procedure for the phenol treatment is as follows:—

(a) Spike Treatment.—The spike with the kernels removed is soaked for 24 hours in a 1% phenol solution, then removed and dried.

(b) Kernel treatment.—The kernels are soaked for 16 hours in water, drained and let dry for 1 hour, then immersed in 5 cc. of a 1% phenol solution for 4 hours and dried on blotting paper. The colour is observed and recorded 4 hours after and again in 2 days after treatment.

METHODS AND MATERIAL

In the fall of 1934, the Cereal Division conducted a number of experiments in order to determine the reliability of the phenol colour test on some of the Canadian Hard Red Spring wheats in order to ascertain whether this means of identification was more accurate and faster than other existing methods. The experiments were planned from the standpoints of the plant breeder, seed merchant and grain trader. Since the plant breeder and seedsmen are both interested in the purity of single lines and the later seed populations, the method of approach to the experiment remained the same.

For the purpose of determining the purity, kernels from several varieties grown at different Experimental Stations scattered throughout Canada and from different crop years were used. The phenol gave distinct colour reactions of light and dark brown.

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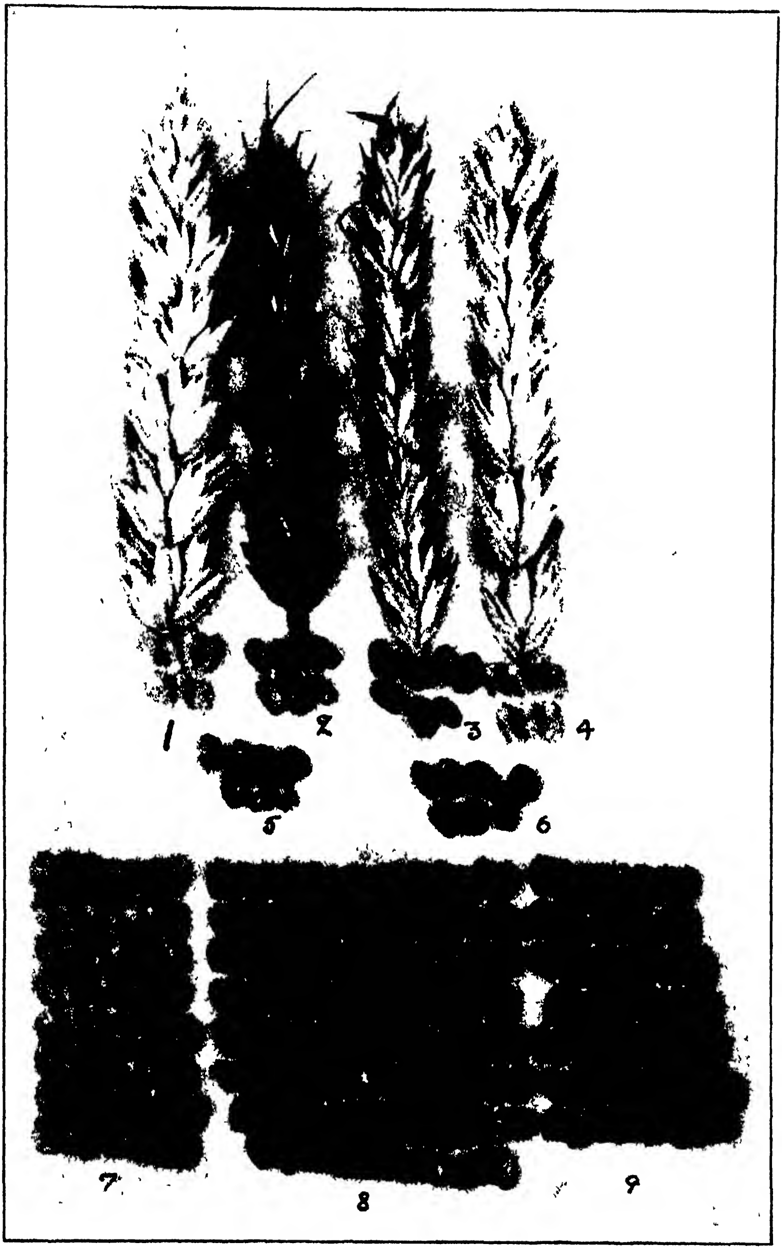


FIGURE 1. Phenol colour reactions with spikes and kernels
1. Red Fife Ott. 17 untreated; 2. Red Fife Ott. 17 treated with Phenol; 3. Garnet Ott. 652 treated with Phenol; 4. Garnet Ott. 652 untreated; 5. F_1 of Red Fife × Garnet cross treated; 6. F_1 reciprocal; 7. F_2 Red Fife parent colour reaction; 8. F_2 Intermediate parent colour reaction; 9. Garnet parent colour reaction.

The group of wheat varieties giving the dark and light brown colour reaction on the kernels were as follows:—

Light Brown Reaction

Red Bobs 222	C.A.N. 1637
Supreme	C.A.N. 1543
Early Triumph	C.A.N. 1291
Ruby Ott. 623	C.A.N. 1511
Parker's Sel.	C.A.N. 1460
Red Fife Ott. 17	C.A.N. 1515

Dark Brown Reaction

Marquis Ott. 15	C.A.N. 1396
Reward Ott. 928	C.A.N. 1509
Garnet Ott. 652	C.A.N. 1316
Ceres	C.A.N. 1263
Huron Ott. 3	C.A.N. 1344

All the spikes of the above varieties turned *brown* in phenol with the exception of the Garnet which remained *white.*

While testing Supreme wheat from various Stations, it was found that, although the spikes appeared morphologically alike, the kernels from one place gave dark brown reactions. This is a typical example of where the phenol test could be usefully employed to bring out differences amongst otherwise morphologically similar varieties.

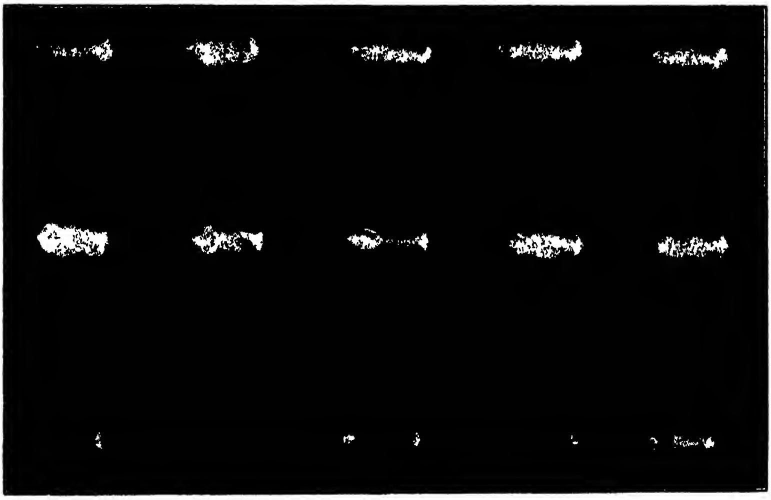
Another valuable application of the phenol test is illustrated in Figure 1 where the F_2 kernels of a Red Fife × Garnet cross gives a distinctive colour reaction from the range found in the parents. It would appear, therefore, that a phenol heterozygous reaction is indicative of hybridization or impurity.

In order to make a practical application which might be helpful to the grain trade in identifying varieties in bulk shipments, representative samples of wheat from the crop year of 1933 were taken from officially gathered overseas shipments and given the standard phenol treatment already outlined. The actual composition of these samples was known from the growing tests conducted in 1934. It is fully realized, at this time, that the phenol test is not in itself infallible, but when considered in conjunction with other kernel characters is a valuable additional aid in identifying the varieties mentioned above. Indeed, the greatest difficulty encountered in testing the reliability of the phenol tests was the differential found in the maturity of the varieties tested. This resulted in a miscellaneous colour reaction for the same variety. The fact that immature kernels did not produce a true varietal colour reaction was ascertained through testing an immature sample of Garnet and Reward wheat which were obtained from the Branch Sub-Station at Fort Smith, Northwest Territories.

Continued efforts to accentuate known characters in order to observe differences between varieties resulted in the successful differentiation of Garnet wheat from all other commonly grown Canadian wheats. This differentiation was accomplished by soaking wheat kernels of the varieties Marquis, Garnet and Reward in water for approximately 16 hours when the outline of the swelling germ could be distinctly observed. From the observation made at Ottawa, Garnet wheat was shown to have its germ

set into the body of the kerrel at a more acute angle than any of the other common wheats usually associated with it in the trade in Canada, namely, Marquis, Reward, Ceres and Early Triumph. When viewed from above, one can see that the knob of the germ is midwide, somewhat pointed at the base and conspicuously protruding at the apex.

The way the germ is inset, general shape of the soaked seeds, along with the phenol colour reaction are presented in Figure 2. The obliqueness of the Garnet germ in comparison to the other varieties is quite noticeable.



Marquis Ott. 15	Reward Ott. 928	Garnet Ott. 652	Ceres	Early Triumph
(..... Dark Brown Colour Reaction			)	(Light Brown Colour Reaction)

Varieties from left to right.

FIGURE 2. The two upper rows of kernels show the accentuated germ characters of five wheat varieties; Lower row of kernels indicates their phenol reactions. Note the acute slope of the Garnet germ.

From Table 1, it seems quite apparent that the length of germ has a tendency to increase with the depth of kernel, and that in Ottawa the germ and kernel size is greater than for the other Stations. The germ length and depth of kernel are undoubtedly more influenced by environment than the variability within the variety. This fact is well brought out in Table 2 where the standard error of the mean of the average measurements is approximately 10 times greater and remains fairly uniform for all varieties.

In Table 2, the measurements of 20 kernels of each of the 5 varieties, Marquis, Reward, Ceres, Garnet and Early Triumph are given as taken from wheat samples grown at the following Experimental Stations: Ottawa, Indian Head, Scott, and Swift Current. The kernels were picked at random from fairly uniform samples that were shipped to Ottawa for milling and baking experiments. From the standard error of the means for these Stations, it can be concluded that there was a small variability in the kernel depth and the germ length of these varieties. The depth of

TABLE I.—AVERAGE MEASUREMENTS AND STANDARD ERROR IN MILLIMETERS OF THE DEPTH OF KERNELS AND LENGTH OF GERMS OF FIVE VARIETIES AT FOUR STATIONS DURING THE SEASON OF 1934

Variety	Ottawa		Indian Head		Scott		Swift Current	
	*Kernel depth in mm	*Germ length in mm	Kernel depth in mm.	Germ length in mm	Kernel depth in mm	Germ length in mm	Kernel depth in mm.	Germ length in mm.
Garnet Ott 652	2 77 ± 0054	2 70 ± 0059	2 53 ± 0053	2 40 ± 0045	2 55 ± 0064	2 49 ± 0050	2 34 ± 0050	2 44 ± 0043
Early Triumph	3 10 ± 0047	2 49 ± 0047	2 96 ± 0052	2 35 ± 0042	2 66 ± 0060	2 26 ± 0064	2 64 ± 0068	2 23 ± 0075
Ceres	3 11 ± .0065	2 52 ± 0061	3 06 ± 0026	2 26 ± 0038	2 82 ± 0061	2 24 ± 0043	2 87 ± 0064	2 22 ± 0045
Reward Ott 928	3 14 ± 0038	2 42 ± 0056	3 02 ± 0034	2 24 ± 0038	2 73 ± 0051	2 24 ± 0048	2 77 ± 0064	2 20 ± 0033
Marquis Ott. 15	3 04 ± 0026	2 35 ± 0064	2 99 ± 0034	2 14 ± 0046	2 78 ± 0058	2 07 ± 0041	2 69 ± 0041	2 10 ± .0045

*The depth of the kernels and length of the germs were measured after soaking the entire kernel in water for 16 hours.

the kernel was taken immediately behind the germ and includes the portion from the apex to the cheeks of the kernel. Each seed was measured after receiving a uniform soaking for sixteen hours. The reason of the greater slope of the Garnet wheat germ by which it can readily be identified from the more common Canadian Hard Red Spring wheats is well presented in Table 2, where the depth of the kernel is almost equal to the length of the germ. It is for this latter reason that the Garnet germ assumes a greater slope.

TABLE 2.—MEAN OF AVERAGE MEASUREMENTS AND STANDARD ERROR IN MILLIMETRES OF THE DEPTH OF KERNELS AND LENGTH OF GERMS OF FIVE VARIETIES GROWN AT FOUR STATIONS DURING THE SEASON OF 1934

Variety	*Depth of kernel in mm.	*Length of germ in mm.
Garnet Ott. 652	2 54 ± 078	2 50 ± 060
Early Triumph	2 84 ± 084	2 33 ± 067
Ceres	2 96 ± 070	2 31 ± .060
Reward Ott 928	2 88 ± 068	2 22 ± 052
Marquis Ott 15	2 87 ± 063	2 14 ± 063

*The depth of the kernels and length of the germs were measured after soaking the entire kernel in water for 16 hours

In Table 3, the measures of significance between means of paired values are presented. Again, it is observed that there is no significant difference between the depth of the Garnet kernels and the length of the germ for the four Stations. Early Triumph is the second longest in length of germ, but, in this case, the significance between the paired means of depth of kernel and length of germ is quite apparent. By pairing the means of the germ length of Marquis and Garnet wheat, the former having the shortest and the latter the longest germ, a very significant difference

FIGURE 3. Accentuated brush characters of three prominent spring wheat varieties: Marquis Ott. 15, Reward Ott. 928 and Garnet Ott. 652 1. Single specimens of Marquis, Reward and Garnet; 2. Garnet; 3. Marquis; 4. Reward.

TABLE 3.—THE t TEST OF SIGNIFICANCE BETWEEN THE MEANS IN MM. OF FOUR STATIONS OF THOSE VARIETIES THAT WERE CLOSEST IN THEIR MEASUREMENTS

Characters compared	t	P
(a) Garnet depth vs. length of germ	2.073	0.2 to 0.1
Early Triumph depth vs. length of germ	8 348	Less than 0.01
(b) Garnet germ vs. Marquis germ	9 970	Less than 0.01
Garnet germ vs. E. Triumph germ	4.216	0 05 to 0.02

is observed. The significant level drops slightly in comparing the germ length of Garnet with that of Early Triumph.

In Figure 3 the brush character is accentuated due to the phenol colouration. The silvery brush of the Marquis wheat, extending from the darkened kernel is a very pronounced characteristic, and the lack of the same in Reward wheat helps to differentiate these two varieties.

SUMMARY

1. An account has been given of the phenol colour reaction of kernels of wheat which were divisible into light and dark brown colour groups. The light brown colour reaction was obtained with Red Bobs 222, Supreme, Early Triumph, Ruby Ott. 623, Parker's Selection and Red Fife Ott. 17, while a dark brown colour reaction was given in the case of Marquis Ott. 15, Reward Ott. 928, Garnet Ott. 623, Ceres and Huron Ott. 3.

2. All the spikes of the above varieties coloured brown with the exception of Garnet which remained white.

3. Immature samples of wheat did not produce the same degree of colour as a fully mature sample.

4. The lengths of the germs and the depths of the kernels of seeds soaked in water for 16 hours were presented for the following varieties: Garnet Ott. 652, Marquis Ott. 15, Reward Ott. 928, Ceres and Early Triumph. The mean measurement of each variety was based on 80 kernels of which 20 were picked at random from samples grown at Ottawa, Indian Head, Scott and Swift Current.

5. Environment contributes more to the variability of the length of germ and depth of kernel than the differences within a variety in a district.

6. Garnet wheat was readily distinguished by its acute germ inset. This fact was again brought out by its mean of average kernel depth in mm. of $2.54 \pm .078$ and its mean germ length in mm. of $2.50 \pm .060$ There was no significant difference between the above two measurements where P is .2 to .1.

7. The Early Triumph kernel approached Garnet closest in germ length and kernel depth, but the difference between the compared means was significant because P is less than .01.

8. In pairing the mean values of Garnet germ vs. Marquis germ (*e.g.* long vs. short) the significance was considerable for P = less than .01 The significant level was lowered to give a P value between .05 to .02

when comparing the Garnet long germ vs. the Early Triumph mid-long germ.

9. The systematic value of the length of germ and depth of kernel was a striking example with the Garnet wheat kernels.

10. It was also evident that the phenol colour reaction accentuates the well known brush characters, and was a valuable means of separating Marquis wheat from a mixture of Garnet and Reward.

11. The data contained in this paper present to the plant breeder additional ways of establishing the genetic composition of hybrids, indentification of pure lines and classification.

12. In commerce, a system of this kind may be used to advantage for the verification of seed samples, the elimination of synonyms among commercial varieties and grading of export samples.

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BIBLIOGRAPHY

1. CLARK, MARTIN and BALL. Classification of American wheat varieties U.S.D.A. Bul No. 1074. 1922.

2. FRIEDBERG, L. Essai de classification des blés d'après leur reaction a l'acide phénique. Annales Agronomique No. 5 . 697-736.

3. — —————. Action de l'acide phénique et de la potasse alcoolique sur la blés. Sélectionneur Vol 2 Fox *1* . 20-29 Imp. Bur of Pl Genetics *4* : 4; 293. 1933.

4. HARRINGTON, J. B. Seedling hairiness as a varietal identification character in wheat. Sci. Agric *13* : 119-125. 1932.

5. HERMAN, W. Die Unterscheidung von Weizensorten durch Phenolfarbung der Samen. Kühn–Archiv Bd. 19. 1928.

6 NEWMAN, L. H. Classification of Canadian spring wheat varieties C.S G.A. Plant Breeder's Bul. No 1. 1926.

7. NEWMAN, L. H. and J. G C. FRASER. Marquis wheat. Dom. of Can. Dept. Agric. Pamphlet No. 95, New Series. 1928.

8. PERCIVAL, J. Wheats in Great Britain. 1934.

9 PFUHL, I. F. Die Unterscheidung der Weizensorten durch Färbung der Korner Angew. Botanik Bd. 9 H. 3, p. 374. 1927.

10. PIEPER. Ein Mittel zur Unterscheidung von Weizensorten am Korn Deutsche Landw. Presse, 49, p. 438. 1922.

11. SCHRÖDER, H. Die Phenolfarbung Roggenkorns als Sortenmerkmal. Fort der Landw. 7 Yahrg. 13 H.1. 1932.

12. SNELL, K. and J. FR. PFUHL. Beitrag aus Morphologie und Systematik der Weizensorten. Mitt. aus der Biol. Reichsanstalt fur Landwirtschaft und Forstwirtschaft. H.39. 1930.

Résumé

Deux nouveaux moyens de distinguer certains blés canadiens. J. G. C. Fraser et F. Gfeller, Ferme expérimentale centrale, Ottawa, Ont.

La réaction de couleur donnée par les grains de blé traités au phénol est le sujet de cette étude. Ces grains se divisaient en deux groupes, à couleur brun clair et à couleur brun foncé. La réaction brun clair a été obtenue sur les Rouge de Bobs 222, Suprême, Triomphe Hâtif, Rubis, Ott. 652, Sélection de Parker et Fife Rouge Ott. 17 tandis que les Marquis Ott. 15, Reward Ott. 928, Garnet Ott. 652, Cérès et Huron Ott. 3 donnaient une réaction brun foncé. Tous les épis des variétés qui précèdent se sont colorés en brun à l'exception du Garnet qui est resté blanc. Les échantillons de blé non mûrs n'ont pas produit le même degré de couleur qu'un échantillon complètement mûr. La longueur des germes et la profondeur des grains de blé trempés dans l'eau pendant 16 heures sont présentées pour les variétés suivantes: Garnet Ott. 652, Marquis Ott. 15, Reward Ott. 928, Cérès et Triomphe Hâtif. La mesure moyenne, pour chaque variété, est basée sur 80 grains, dont 20 ont été pris au hasard sur des échantillons produits à Ottawa, Indian Head, Scott et Swift Current. La longueur du germe et la profondeur du grain varient suivant les conditions environnantes, qui paraissent être un facteur plus important sous ce rapport que les différences présentées par une variété. Le blé Garnet se distinguait facilement par son germe saillant, faisant encore ressortir la profondeur moyenne du grain qui était en mm. de 2 54 .078 et la longueur moyenne du germe, en mm. 2 50 0 060. Il n'y avait aucune différence significative entre les deux mesures qui précèdent lorsque P est 2 à .1. Le grain du Early Triumph est celui qui se rapprochait le plus de celui du Garnet au point de vue de la longueur du germe et de la profondeur du grain, mais la différence entre les moyennes comparées était significative parce que P n'atteint pas 01. Une comparaison des valeurs moyennes du germe du Garnet et du germe du Marquis (long contre court) révèle une différence considérable, savoir P = moins que 01. Le niveau significatif a été abaissé pour donner une valeur P entre 05 et 02 en comparant le long germe du Garnet au germe de longueur intermédiaire du Early Triumph. La valeur systématique de la longueur du germe et de la profondeur du grain est un exemple frappant en ce qui concerne les grains du blé Garnet. Il est évident également que la réaction de couleur au phénol accentue les caractères de brosse bien connus et que c'est là un moyen utile de séparer le blé Marquis d'un mélange de Garnet et de Reward. Les données contenues dans ce travail offrent au sélectionneur de plantes de nouveaux moyens d'établir la composition génétique des hybrides, l'identification des lignes pures et la classification. Un système de ce genre pourrait être employé avantageusement dans le commerce pour la vérification des échantillons de semence, l'élimination des synonymes parmi les variétés commerciales et le classement des échantillons d'exportation.

TIME OF HEADING AND FLOWERING OF EARLY, MEDIUM, AND LATE TIMOTHY PLANTS AT DIFFERENT LATITUDES

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INTRODUCTION

The relation between the time of flowering and the seasonal conditions at different latitudes, or of any other biological phenomenon, is a complex one. According to Hopkins' Bioclimatic Law (5), if other conditions, such as those relating to longitude, altitude, distance to large bodies of water, and other factors which may have an effect on local climates are equal, then the time of flowering, or any other periodical event in the spring, should progress from south to north, in the northern hemisphere, over the entire range of latitude where any species of plant under consideration may grow, at the uniform rate of one fourth of a degree of latitude each day.

In 1920, two years after Hopkins' Bioclimatic Law had been published, Garner and Allard (*4*) described the results of a study which they had conducted on the effects of different lengths of day upon the growth of plants of different kinds. They found that some plants do not produce inflorescences unless they are growing under days exceeding some minimum length—which varies for different species and varieties; plants of this kind are called long-day plants. Other plants produce inflorescences only when the length of day is reduced so that it does not exceed some certain maximum length; they are known as short-day plants. Still another group of plants seem more or less indifferent to length of day. Reproductive processes, in this type, are less dependent upon the season than in the other two groups.

Timothy *(Phleum pratense)* has the characteristics of a long-day plant. If timothy plants are transplanted to a greenhouse early in the winter, and are grown there with normal illumination, even though soil and temperature conditions are favourable for vigorous growth, the stems do not become elongated to form culms until spring. The formation of inflorescences is delayed until nearly as late in the spring as on plants which have been out of doors, in a more or less dormant condition, during the entire winter. If at any time during the winter, however, the length of day is artificially extended from sundown to about midnight by means of a 200-watt ordinary electric light bulb suspended over the timothy plant in the greenhouse, the stems begin to grow in length. Within a few weeks inflorescences appear, and a little later the florets bloom in the same way as on timothy plants in meadows during late spring and early summer (*1*, p. 45–49).

Plants of two of the strains of timothy, numbers 11902 and 12421, used in this investigation also were grown in 1928 and 1929 in an earlier experiment, at six stations, ranging from Savannah, Georgia, at 32 degrees

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6 minutes, to Fairbanks, Alaska, at 64 degrees 51 minutes north latitude. The time when the first florets bloomed progressed from south to north, not at a uniform rate, but at a rate which was constantly accelerated as the season advanced. This effect was attributed to the greater lengths of day occurring during late spring and early summer, at northern than at southern latitudes (*2*).

Progress of the Season for Heading and Flowering of Early, Medium and Late Strains of Timothy

In the experiment to which reference has been made, the progress of the season of the later strain, 12421, differed somewhat from that of the earlier strain, 11902. This fact indicated the desirability of conducting further investigations of the way in which the season for the appearance of the inflorescences, or heads, and the beginning of the flowering process, progresses from one latitude to another. Accordingly, 13 strains of timothy which range, with fairly uniform gradations, from very early to very late were grown in 1933 at three stations at different latitudes. The locations of these stations are as follows:—

—	Latitude		Longitude		Altitude feet
	Degrees	Minutes	Degrees	Minutes	
Washington, D.C., U S.A.	38	54	77	3	50
North Ridgeville, Ohio, U.S.A.	41	23	82	2	750*
Guelph, Ontario, Canada	43	33	80	16	1120

*Approximate.

TABLE 1.—DATES WHEN THE TIP OF THE FIRST INFLORESCENCE, EMERGED FROM THE LEAF SHEATHS WITHIN WHICH IT HAD DEVELOPED, ON THE TIMOTHY PLANTS GROWN AT STATIONS AT 3 DIFFERENT LATITUDES. (IN 1933.)

F.C. number	Washington, D.C.	North Ridgeville, Ohio	Guelph, Ontario
19456	May 13	May 22	June 3
19458	May 17	May 25	June 2
15092	May 23		June 4
11902	May 24	May 29	June 8
6127	June 2	June 3	June 8
6743	May 31	June 7	June 11
9220	June 10	June 10	June 12
12421	June 14	June 20	June 20
15485	June 23	June 21	June 25
19416	June 23	June 25	June 24
15445	July 1	June 28	June 24
19459	July 10	July 3	June 26
19460	July 16	July 9	June 30

The plants of each strain had been propagated vegetatively from the same original plant, so there were no genetical differences among them, as would have been the case if they had been grown from seed. The plants were transplanted to the locations where they were grown in 1932, so that all plants had become well established when growth began in the Spring of 1933.

The strains of timothy used were F.C. selection numbers,[4] developed at the Timothy Breeding Station which is conducted co-

[4] A series of numbers used by the Division of Forage Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture.

operatively at North Ridgeville, Ohio, by the Division of Forage Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and the Department of Agronomy of the Ohio Agricultural Experiment Station. Records were obtained of the date when the tip of the first head on each plant emerged from within the leaf sheaths in which it had been enclosed, and of the date when the first florets bloomed on each plant. Observations and notes were also made to show whether the stems of the plants were upright in their habit of growth, or whether they were more or less declined at the base.

TABLE 2.—DATES WHEN THE FIRST FLORETS BLOOMED ON TIMOTHY PLANTS GROWN AT STATIONS AT 3 DIFFERENT LATITUDES. (IN 1933)

F.C. number	Washington, D.C.	North Ridgeville, Ohio	Guelph, Ontario
19456	May 27	June 5	June 20
19458	June 2	June 8	June 20
15092	June 6	June 10	June 22
11902	June 8	June 12	June 25
6127	June 13	June 16	June 25
6743	June 14	June 22	June 28
9220	June 23	June 27	June 28
12421	June 28	June 29	July 3
15485	July 3	July 4	July 8
19416	July 10	July 5	July 6
15445	July 13	July 10	July 7
19459	July 25	July 15	July 8
19460	July 31	July 22	July 15

Early, Medium and Late Strains of Timothy Respond Differently to Conditions at Different Latitudes

The dates when the tip of the first head appeared on each plant, at each one of the three stations, is shown in Table 1, and similar information in regard to the time of flowering is shown in Table 2. The dates when florets began to bloom is also presented, in graphical form, in Figure 1.

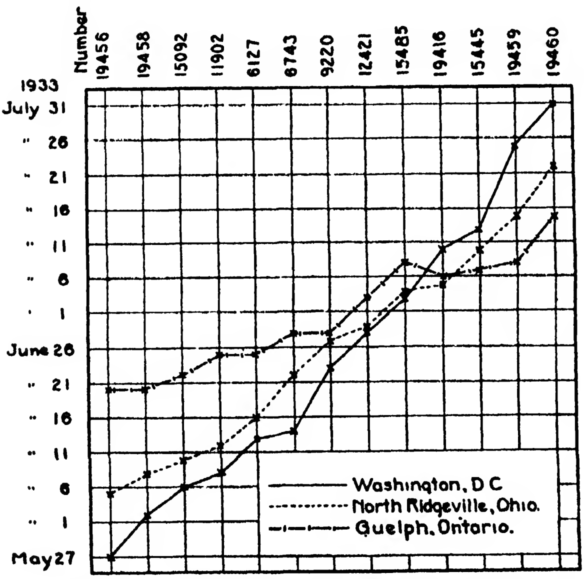

FIGURE 1. Dates when the first florets bloomed on timothy plants propagated vegetatively from the original plants of the selections indicated. These plants were grown at Washington, D.C., and at North Ridgeville, Ohio, U.S.A., and at Guelph, Ontario, Canada, with normal illumination. (In 1933.)

The records which have been presented show that the florets of the plants of the earliest timothy selection, 19456, bloomed at Washington 24 days before they did at the most northern station at Guelph. The other selections which are earlier than medium bloomed first at Washington, then at North Ridgeville, and finally at Guelph, though the differences in time of blooming at the three latitudes

was gradually less, as the selections rank later in the series. The time of flowering of some of those selections which rank about midway, and a little later, in the series, was approximately the same at all three stations. In the case of the 3 latest selections, the progress of the season for heading and blooming was reversed, occurring first at the northern station, then at the one midway between the others, and finally at the southern station. The florets of the plants of the latest selection, 19460, bloomed at Washington 16 days after they did at Guelph, more than 4.5 degrees further north.

In a general way, the statements which have been made in regard to the time of flowering of these timothy plants at 3 different latitudes also apply to the dates on which the tips of the first heads appeared on these plants.

Comparison of the Results with those Predicted by Hopkins' Bioclimatic Law

According to Hopkins' Bioclimatic Law, if other conditions are equal, the season for any periodical biological event, progresses in the spring from south to north at the uniform rate of one-fourth of a degree per day. Since Guelph is slightly more than 4 5 degrees north of Washington, if this law were equally applicable to these timothy selections, they should have all headed and bloomed at Guelph about 18 days after they did at Washington. As has already been stated, the earliest selection bloomed 24 days later at Guelph. The next to the earliest selection, 19458, did bloom as predicted exactly 18 days later at Guelph than at Washington. The two next earliest selections bloomed 16 or 17 days later at Guelph than at Washington; the slight deviations from the 18 days predicted possibly may be accounted for by differences in longitude, altitude, distance from large bodies of water or other local conditions recognized in Hopkins' Bioclimatic Law as factors which affect the progress of the season. There is no statement in this law, however, suggesting why the season for heading and flowering of the 3 latest selections should progress from north to south.

Time of Heading and Flowering in Relation to the Lengths of Day Occurring at Different Latitudes

What hypothesis may be offered for the different ways in which the season for heading and blooming of the early, medium, and late strains of timothy progressed?

In an experiment conducted in 1931 by Evans and Allard (3), most of the same selections which were used in this investigation were grown under days, artificially made of different uniform lengths, *i e.*, 10 0, 12.0, 12.5, 13.0, 13 5, 14 0, 14 5, 15 0, 16 0, 17.0 and 18.0 hours. Plants of each strain were grown under part or all lengths of day. The early, medium, and late strains of timothy responded differently; a difference of half an hour, near the critical length of day under which development of stems and inflorescences formed, had a profound effect upon the growth of the plants.

With 10 0 hours light each day, plants of only the earliest selection, 19456, produced culms and inflorescences. With 12 5 hours of light, the next three earliest selections also produced inflorescences; under this length of day, all of those selections which are later, when growing under natural conditions, made only vegetative growth. When the plants of the later strains were grown under progressively longer days, those selections

which are increasingly later responded by producing culms and inflorescences. For the three latest selections from 14.5 to 15.0 hours of light were required for reproductive growth. In the case of all strains, the time required for the growth of culms and inflorescences became shorter, as the length of day increased from the minimum to the optimum for this development. If the length of day is near the minimum, the time when florets begin to bloom may be a month or more later than if the length of day is 3 or 4 hours above the minimum.

The length of day on any date during late spring or early summer, when plant growth is most active, varies at different latitudes. About June 21, when the maximum daily duration of possible sunshine occurs, the length of day, from sunrise to sunset, is as follows at the stations indicated:—[5]

Washington, D.C.	14 hours 55 minutes
North Ridgeville, Ohio	15 hours 8 minutes
Guelph, Ontario	15 hours 29 minutes

The early, medium, and late selections of timothy grown at different latitudes responded, in respect to the time heads appeared and florets began to bloom, in much the same way as they did to days of different uniform lengths in the earlier experiment. The length of any day during late spring and early summer gradually increases from south to north. The differences in day length at the three stations where this investigation was conducted seem to furnish the key to the explanation of the results which were obtained.

At the southern station, Washington, D.C., the temperature becomes high enough for plant growth to take place, several weeks earlier in the spring than at the northern station at Guelph, Ontario. The days are of sufficient length at Washington compartively early in the spring for the development of inflorescences of the earliest selection, 19456, consequently florets began to bloom 24 days earlier than at Guelph, where temperature was the limiting factor. In the case of the latest selections, however, which require relatively long days for the formation of inflorescences, length of day instead of temperature, was the limiting factor. Notwithstanding the favourable temperature during the spring, the development of inflorescences was delayed in these late selections until the season had advanced to a time when the days had become long enough for reproductive development. It may be attributed to the fact that this condition of day length was fulfilled at Guelph earlier than at North Ridgeville, and at North Ridgeville earlier than at Washington, that the season for heading and blooming, in the three latest strains of timothy used in this investigation, progressed from north to south, instead of from south to north.

In the earlier experiment, conducted in 1931, it was found that when timothy plants were grown under lengths ot day which were near the minimum for the formation of inflorescences, the stems were more or less declined at the base, while other plants of the same strains, grown under favourable lengths of day, had upright stems. At each of the three stations where these timothy selections were grown in 1933, the stems of the three latest ones, 15445, 19459 and 19460, were much declined at the base. The

[5] Data supplied by the Weather Bureau, United States Department of Agriculture.

stems of 19416, the fourth from the latest selection, were declined at Washington, were slightly declined at the base at North Ridgeville, but grew upright at Guelph. The stems of the plants of all other selections, at all stations, were upright in their habit of growth. This result suggests that for the three latest selections, the lengths of day which occurred at all three stations were near the minimum under which reproductive growth occurs in these selections; while for the plants of timothy 19416, the lengths of day approach the optimum at Guelph, are somewhat below the optimum at North Ridgeville and even more so at Washington.

SUMMARY

A series of 13 strains of timothy ranging by fairly uniform gradations from very early to very late were grown at stations at three different latitudes, extending from Washington, D.C., at 38 degrees 54 minutes to Guelph, Ontario, Canada, at 43 degrees 33 minutes north latitude. The third station, North Ridgeville, Ohio, approximately midway between the other stations, is at latitude 41 degrees 23 minutes.

The florets of the earliest strain began to bloom at the southern station 24 days sooner than at the northern station. In selections progressively less early, the difference between the time of heading, or appearance of the inflorescence, and of blooming at the southern and the northern station gradually decreased. Those selections which are approximately medium between the earliest and latest in the series produced heads and the florets bloomed at nearly the same time at all three stations. The progress of the season for heading and blooming of the three latest strains of timothy was from north to south, instead of from south to north.

In very early strains heads develop and the flowering process occurs with days 10 to 12 hours long. In strains which are later under natural conditions, longer days are required for these processes, if the plants are grown under days artificially made of uniform lengths. At the southern station where this experiment was conducted, the lengths of day during late spring and early summer are not as great as at the stations further north. For the earliest strains, the lengths of day at the southern station are sufficient for the development of heads to begin before the temperature becomes high enough for active growth at the stations further north. In the case of very late strains of timothy, on the other hand, length of day apparently is the limiting factor at the latitudes where this experiment was conducted. Since the minimum length of day in the spring is attained, in the northern hemisphere at stations which are relatively far north, sooner than at stations further south, the season for heading and flowering of these very late strains of timothy consequently progresses, in the latitudes where this experiment was conducted, from north to south.

LITERATURE CITED

1. Evans, Morgan W. The life history of timothy. U.S. Dept. Agri. Dept. Bul. 1450. p. 1-56. 1927.

2. ———————. Relation of latitude to time of blooming of timothy. Ecology. *12* : 182-187. 1931.

3. ——————— and Allard, H. A. Relation of length of day to growth of timothy. Jour. Agri. Res. (U.S.), *48* : 571-586. April 1, 1934.

4. Garner, W. W. and Allard, H. A. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Agri. Res. (U.S.), *18* : 553-606. 1920.

5. Hopkins, A. D. The bioclimatic law. U.S. Dept. Agri. Weather Bureau; Monthly Weather Review Supplement No. 9, p. 1-42. 1918.

Résumé

Epoque de l'épiage et de la floraison des plantes hâtives, intermédiaires et tardives de fléole (Mil) sous différentes latitudes. M. W. Evans et H. A. Allard, Ministère de l'agriculture des Etats-Unis, et O. McConkey, Collège d'agriculture de l'Ontario, Guelph, Ontario.

Une série de 13 espèces de fléole des prés (mil) variant par gradations assez uniformes depuis une espèce très hâtive jusqu'à une espèce très tardive, a été cultivée sous trois latitudes différentes, depuis Washington, D.C. à 38 degrés 54 minutes jusqu'à Guelph, Ontario, Canada, à 43 degrés 33 minutes latitude nord. La troisième station, North Ridgeville, Ohio, à peu près à mi-chemin entre les autres, est à 43 degrés 23 minutes de latitude. Les fleurons de l'espèce la plus hâtive ont commencé à fleurir à la station du sud 24 jours plus tôt qu'à la station du nord. Dans les sélections progressivement moins hâtives, la différence entre l'époque de l'épiage (ou l'apparition de l'inflorescence), et de la floraison, entre la station du sud et celle du nord, diminuait graduellement. Ces sélections, qui sont approximativement intermédiaires entre l'espèce la plus hâtive et l'espèce la plus tardive de la série, ont produit des épis et les fleurons ont fleuri à peu près à la même date sur toutes les trois stations. La marche de la saison pour l'épiage et la floraison des trois espèces les plus tardives de fléole allait du nord au sud, au lieu d'aller du sud au nord. Dans les espèces très hâtives, l'épiage et la floraison se produisaient lorsque le jour a une longueur de 10 à 12 heures. Chez les espèces qui sont plus tardives dans des conditions naturelles, des journées plus longues sont nécessaires pour ces procédés, lorsque les plantes sont cultivées dans des journées de longueur artificiellement uniforme. A la station du sud où cette expérience a été conduite, les jours de la fin du printemps et du commencement de l'été ne sont pas aussi longs qu'aux stations situées plus au nord. Pour les espèces les plus hâtives, la longueur des jours à la station du sud est suffisante pour que les épis commencent à se développer avant que la température se réchauffe suffisamment pour favoriser une végétation active aux stations situées plus au nord. Par contre, dans le cas des espèces très tardives de fléole, la longueur du jour paraît être le facteur limitatif, aux latitudes où cette expérience a été conduite. Comme la longueur minimum du jour dans l'hémisphère du nord, au printemps, est atteinte plus tôt aux stations relativement loin dans le nord qu'aux stations plus au sud, la saison d'épiage et de floraison de ces espèces très tardives de fléole va donc en progressant du nord au sud, dans les latitudes où cette expérience a été conduite.

STUDIES IN INTERSPECIFIC CROSSING WITH *MELILOTUS* AND IN INTERGENERIC CROSSING WITH *MELILOTUS MEDICAGO* AND *TRIGONELLA*[1]

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The investigations discussed in this paper were carried out during the years 1931–34. The purpose of the work was fourfold; (*1*) to determine to what extent it may be possible to produce hybrids, by controlled crossing, between the more commonly grown species of sweet clover; (*2*) to learn something of the possibilities of intergeneric crossing between *Melilotus*, *Medicago* and *Trigonella;* (*3*) to study the behaviour of any hybrids which might result from these crosses with respect to their value in crop improvement; and (*4*) to endeavor to throw some light upon the origin of certain new plant types which have from time to time appeared in our sweet clover plots and which, we have reason to suspect, may have resulted from natural crosses in which common white blossom sweet clover was one of the parents.

Natural crosses between certain members of the *Melilotus* group have been observed in a few instances. Hausskneecht (*5*) described hybrids which he believed to have resulted from the spontaneous crossing of *Melilotus albus* and *Melilotus officinalis*. These plants he observed to be intermediate between the two parents with respect to many characters. The flower colour is described as showing "a little yellowish tint which appears, if closely examined, like a dirty white". Their pollen grains were of abnormal shape and structure and they set little seed.

Kirk (*6*) obtained only one natural hybrid from 11,400 plants arising from seed harvested from a row plot of *M. albus* which was grown under conditions most favourable for natural crossing. Ten varieties or species of yellow blossom sweet clover surrounded the plot from which this seed was gathered. The F_1 hybrid possessed pale yellow flowers. Flowers of a "dull white" colour, showing only a slight yellowish tint, appeared in the F_2 progeny, Kirk (*7*).

Sylven (*11*) observed two plants, grown from a lot of seed imported from Canada, which he believed to be natural hybrids between *M. albus* and *M. officinalis*. These plants were intermediate between the parent species with respect to most characters. They produced flowers of a "pale yellow or yellowish white" colour. The pollen produced by them was from 50% to 80% sterile.

The possibility of producing interspecies hybrids in *Melilotus*, by means of artificial cross-pollination, appears to have received little attention. Kirk (*8*) made an extensive series of crosses between *M. albus* and *M. officinalis* and did not obtain a single hybrid therefrom. He observed that such cross-pollinations usually resulted in the formation of seeds

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but that the seeds so produced failed to develop normally. They were small, shrunken and non-viable.

Dann (*2*) attempted to produce hybrids between *Medicago* and *Melilotus*. When *Melilotus* was used as the female parent not a single seed was produced. A few poorly developed, non-viable seeds were obtained from the reciprocal cross.

DESCRIPTION OF MATERIAL

The material employed in these experiments consisted mainly of a number of varieties and selections which had been grown and observed for several years in our breeding nurseries and in addition a number of single plants grown from commercial seed. A brief description of the various varieties and selections follows:

Group I, *Melilotus albus* Desr., consisting of the following material: "Arctic" a semi-dwarf, hardy variety of Siberian origin, which is widely grown in Saskatchewan. Several lines which had been previously selected from Arctic and inbred for two or more generations were also used, mainly because of marked differences in flower structure. Four varieties of the dwarf branching or "Alpha" type and a number of individual plants grown from ordinary commercial seed were also included.

Group II, *Melilotus officinalis* (L) Desr., containing two of the more widely grown yellow blossom varieties, Albotrea and Zouave. The former variety is quite typical of this species. Zouave is distinct among the yellow blossom sorts in that it produces an upright growth in the seedling year. Both these varieties are non-self-pollinating. Plants grown from commercial seed were also available.

Group III, *Melilotus* sp., contains only one variety—Redfield Yellow. This is a very late flowering, leafy type which originated at Redfield, South Dakota. This variety is largely self-pollinating, a fact which may explain the unusual uniformity which it possesses. At various times this variety has been regarded as a member of the *M. officinalis* and *M. sauveolens* groups. Dr Samuel Garver, Redfield, South Dakota, has the following to say regarding the botanical position of this variety: "We have not yet been able to identify this variety botanically. For a time we thought it was *M. sauveolens* but it does not entirely answer to the description of that species as given in the German Monographs on the genus . . . ". On the other hand Brink (*1*) states that it is doubtful whether Redfield Yellow belongs to *M. officinalis*.

Group IV, *Medicago media* Pers., contains a number of selections from each of several strains of the "Grimm" variety. The individual plants exhibit marked differences, especially with respect to seed setting.

Group V, *Trigonella coerulea* (L) Ser., consisted entirely of plants grown from commercial seed. This material possessed unusual uniformity.

EXPERIMENTAL METHODS

Most of the crossing work was carried out in a greenhouse from which insects, with the exception of aphids, were excluded by means of fine mesh wire screening. Aphids, which appear to be of little consequence in the transportation of pollen, were controlled by fumigation. Some crosses

were made also in the field nurseries in which cases either the entire plant was protected by a wire screen or a cotton cage or the crossed racemes were enclosed in glassine bags. Seed setting on field crosses was not significantly different from that obtained under greenhouse conditions. Plant material was grown in the greenhouse and crosses were made throughout the entire year, so that a wide range of conditions, with respect to length of day and to temperature, were experienced. In addition artificial light was used in some cases to hasten maturity. None of these conditions appeared to have markedly affected the seed setting.

Parent material was either grown from seed sown directly into pots in the greenhouse or was transplanted from the field nursery to pots and taken to the greenhouse.

Three methods of emasculation were practiced. The particular method to be used was decided upon after an examination of the flowers of the parent material. Sweet clover plants which possessed the non-self-pollinating flower structure, as described by Kirk and Stevenson (*9*), were easily and effectively emasculated by use of the suction method devised by Kirk (*8*) or by simply removing the petals from the fully open flowers and blowing the pollen off. This latter method, while slightly less certain than the suction method, is relatively rapid and was satisfactory on this type of plant. Self-pollinating types of sweet clover, also all alfalfa and *Trigonella* plants, were emasculated in the bud stage. Flowers which would be expected to open under normal conditions in from three to four days were selected. The procedure was to split the standard down the back thus exposing the anthers which were readily removed by means of a dissecting needle. A binocular magnifier (×2 or ×3) with head attachment, so that the hands are left free, was found to be a most valuable aid in emasculation and pollination work.

Pollination was in all cases accomplished by gathering the pollen on the broad end of a toothpick and applying it directly to the stigmas of the emasculated flowers. When fully open flowers were emasculated they were pollinated immediately but those treated in the bud stage were not pollinated until the petals unfolded in the normal manner. This time varied from two to five days after emasculation.

In all cases when the flowers on a raceme were emasculated for crossing, those on another raceme of the same plant were emasculated at the same time. One of these racemes was pollinated and the other left unpollinated to serve as a control on the effectiveness of the emasculation. In addition several racemes were self-pollinated on each plant in order to observe the effect of selfing on seed setting and development.

The number of pods formed were recorded as soon as they appeared and their development from then on was closely observed. The seeds obtained from crossed flowers were carefully examined and a description recorded. They were then planted and the resulting plants, if any, were examined for hybrid characters. Crosses, as far as possible, were made in both directions.

EXPERIMENTAL RESULTS

I. Interspecific Crossing with Melilotus

Over 7000 crosses, involving a large number of parents, were made between *M. albus* and *M. officinalis*. When the white blossom plants

were pollinated with pollen from any of the *M. officinalis* parents, or when the reciprocal crosses were made, no hybrids resulted. Many of these crosses produced pods but most of these ceased development at an early stage (about 10 days after pollination). When the female parent was of the *M. albus* group they turned yellow and dropped off the plant in from 19-21 days. When the cross was made in the opposite direction they dropped from the plant in from 17-19 days after pollination. The seeds contained in these pods were always smaller than normal seeds and were shrunken and of a greenish brown colour. They failed to germinate in every case. The few pods which developed normally proved to have resulted from self-fertilization without exception. Some typical results from such crosses are presented in Table 1.

TABLE 1.—SOME TYPICAL RESULTS OBTAINED BY POLLINATING FLOWERS OF *M. albus* WITH POLLEN FROM *M. officinalis*

PARENTS Female × Male	No of flowers cross-pollinated	Per cent of cross-pollinated flowers which produced viable embryos	Per cent of cross-pollinated flowers which produced abortive seed	Per cent of viable seed which produced hybrid plants	Per cent of viable seed which produced selfs
Arctic No 1 × Albotrea	126	8	35	0	100
Arctic No 2 × Albotrea	118	7	28	0	100
Arctic No. 3 × Albotrea	120	11	37	0	100
Arctic No 4 × Albotrea	119	6	33	0	100
Arctic No 5 × Albotrea	263	13	39	0	100
Alpha No 1-42 × Albotrea	90	8	21	0	100
Alpha No 3-82 × Albotrea	63	6	3	0	100
Arctic No 1 × Zouave	144	5	45	0	100
Arctic No 2 × Zouave	254	6	39	0	100
Arctic No 3 × Zouave	120	11	37	0	100
Arctic No 4 × Zouave	100	8	59	0	100
Arctic No 5 × Zouave	85	7	38	0	100
Alpha No. 1-42 × Zouave	117	12	35	0	100
Alpha No. 3-82 × Zouave	140	0	0	0	100

NOTE. The percentages of viable seeds produced on these cross-pollinated flowers were not significantly different from those produced by the controls.

From more than 2700 crosses made by pollinating *M. albus* parents with Redfield Yellow pollen, or from the reciprocal crosses, very different results were obtained. Most of these crosses resulted in the formation of pods. From certain matings these were all normal; from others they were nearly all normal and from still others a high percentage were of the abortive type. In table 2 are presented data obtained from some of these crosses. The *M. albus* parents are the same ones that were used in the *M. albus* × *M. officinalis* crosses shown in Table 1.

From these data it may be noted that the production of viable seed was markedly higher than from the *M. albus* × *M. officinalis* crosses, shown in Table 1, while the percentage of crossed flowers which produced aborted seed were very much lower in most cases, and in two cases no seeds of this type were obtained. From several matings of Arctic × Redfield Yellow every viable seed produced hybrid plants even though the control racemes produced the usual percentage of selfed seeds. Since the

TABLE 2.—SOME TYPICAL RESULTS OBTAINED BY POLLINATING FLOWERS OF *M. albus* WITH POLLEN FROM REDFIELD YELLOW (*Melilotus* SP.)

PARENTS Female × Male	No of flowers cross-pollinated	Per cent of cross-pollinated flowers which produced viable seed	Per cent of cross-pollinated flowers which produced abortive embryos	Per cent of viable seed which produced hybrid plants	Per cent of viable seed which produced selfs
Arctic No 1 × Redfield Yellow	103	77	0	100	0
Arctic No. 2 × Redfield Yellow	106	57	10	100	0
Arctic No. 4 × Redfield Yellow	96	75	6	100	0
Arctic No 5 × Redfield Yellow	138	87	0	100	0
Alpha No 1-42 × Redfield Yellow	105	18	37	40	60
Alpha No. 3-82 × Redfield Yellow	318	14	20	66	34
Alpha No. 5-1 × Redfield Yellow	124	40	0	84	16

control flowers were emasculated at the same time and by the same method as the crossed flowers, we can only conclude that the Redfield Yellow pollen was able, for some reason, to effect fertilization even in competition with pollen produced by the female plant itself. From other matings, and notably from the Alpha × Redfield Yellow crosses, not only were abortive seeds obtained but a fairly large percentage of the normal seeds proved to have resulted from self-fertilization, indicating a less degree of compatibility than was shown with the Arctic female parents.

Not all of the matings, however, involving Arctic as one of the parents, were equal in this respect. Also there appeared to be as marked differences in the compatibility of various matings involving individuals from any one variety as there were between the matings involving the different varieties of *M. albus*. Likewise when any particular plant of *M. albus* was crossed with a number of different plants of Redfield Yellow, equally variable results were obtained.

It is therefore reasonable to assume, since hybrids were obtained readily from the *M. albus* × Redfield Yellow crosses, whereas efforts to cross *M. albus* with *M. officinalis* did not meet with success, that Redfield Yellow is distinct, genetically, from the other yellow flowered varieties or selections used in these crosses.

Further proof that Redfield Yellow is genetically distinct was evidenced by the results obtained from pollinating Redfield Yellow with

TABLE 3—SOME TYPICAL RESULTS OBTAINED WHEN FLOWERS OF *M officinalis* WERE POLLINATED WITH POLLEN FROM REDFIELD YELLOW AND WHEN THE RECIPROCAL CROSS WAS MADE

PARENTS Female × Male	No of flowers cross-pollinated	Per cent of cross-pollinated flowers which produced viable seed	Per cent of cross-pollinated flowers which produced abortive embryos	Per cent of viable seed which produced hybrid plants	Per cent of viable seeds which produced selfs
Albotrea × Redfield Yellow	115	1	36	0	100
Zouave × Redfield Yellow	363	8	29	0	100
Redfield Yellow × Albotrea	117	7	42	0	100
Redfield Yellow × Zouave	107	6	16	0	100

pollen from Zouave and from Albotrea and from reciprocals of these crosses. From these matings no hybrids were produced. A number of abortive seeds resulted, however, as in the *M. albus* × *M. officinalis* crosses. In Table 3 are presented data from some of these crosses.

II. Intergeneric Crossing

Intergeneric crosses were made as follows:

Medicago × *Melilotus officinalis*	2084
Medicago × *Melilotus albus*	2990
Medicago × *Trigonella coerulea*	1003
Trigonella coerulea × *M. officinalis*	2035
Trigonella coerulea × *M. albus*	3460

The figures given include all cross-pollinations made between the species concerned irrespective of the direction of the cross.

When alfalfa flowers were pollinated with pollen from any of the varieties or species of either white blossom or yellow blossom sweet clover not a single seed was formed. From the reciprocal crosses, however, a few matings produced abortive seeds which behaved, in their development, similar to those obtained from the sweet clover species crosses. Approximately 75% of these reciprocal matings, however, failed to produce even abortive seeds It is apparent that the type of incompatability present in most of these crosses was such that it prohibited fertilization.

When any of the yellow blossom sweet clovers were pollinated with pollen from *Trigonella coerulea*, or when the reciprocal crosses were made, not a single seed was formed Crosses in which the white blossom sweet clovers were pollinated with pollen from *Trigonella coerulea*, however, produced seeds in many cases. Only a small percentage of these were of the abortive type. The percentage of normal seeds produced was greatly in excess of the seed setting obtained on the control racemes. These normal seeds, however, produced plants which, in all cases, closely resembled the maternal parent. Not a single one of them showed *Trigonella* characters. The consistency with which these results were obtained when the crosses were repeated indicated that they could not be explained on the basis of faulty emasculation. The possibility of apomictic development is being investigated. No seeds of any kind were obtained from the reciprocal crosses.

Crosses involving *Medicago* and *Trigonella* did not result in the production of a single seed irrespective of the direction in which the pollinations were made.

III. The Occurrence and Development of Abortive Embryos.

In the course of these and other experiments it was noted that the occurrence of abortive embryos in sweet clover was not peculiar to interspecific and intergeneric crosses only. Premature, shrunken, non-viable seeds resulted frequently from self-fertilized flowers of all of the various species and varieties worked with. Nor was this phenomena peculiar to plants grown under greenhouse conditions since similar seeds have been produced from field selfings.

The occurrence of these abortive embryos on self-fertilized plants was first observed in the inbred lines of *M. albus* and was particularly common in those of the non-self-pollinatirg type. Similar conditions were observed on several occasions, in self-fertilized flowers of *Medicago* and of *Trigonella coerulea*.

In the case of interspecific crosses involving the *M. albus* and *M. officinalis* groups a high percentage of the cross pollinated flowers (in one cross 59%) produced abortive embryos. Crosses between the same *M. albus* parents and Redfield Yellow, however, showed considerable variation in this respect. Certain inbred lines of Arctic, when crossed with Redfield Yellow, produced only normal seeds, all of which produced hybrid plants, while other lines produced a few seeds of the abortive type. Certain lines of Alpha, on the other hand, when crossed with Redfield Yellow, produced a fairly high percentage of abortive embryos.

The percentage of abortive embryos produced by these crosses did not appear to be influenced at all by the direction in which the crosses were made. The behaviour of the hybrid embryos produced on *M. officinalis* females, however, differed from those on the *M. albus* females in that the former dropped from the parent plants about two days earlier.

The writers are indebted to Dr. W. P. Thompson[4] for the following data regarding the fertilization and subsequent development of embryos from interspecific crosses involving the *M. albus* and *M. officinalis* groups. He observed that in all crosses pollen tube growth appeared to be normal. Fertilization occurred within twelve hours after pollination and practically all cross-pollinated flowers produced embryos. In Table 4 are presented comparative data relative to the development of these hybrid embryos.

TABLE 4.—COMPARATIVE DEVELOPMENT OF HYBRID AND SELFED EMBRYOS FROM ARCTIC × ZOUAVE CROSSES

Period of observation	Relative development	
	Hybrid embryo	Selfed embryo
First 7 days	Growth much like selfed sib but slower.	
At 7 day	Length 190-230 U.	Length 250-270 U.
At 10 day	Hybrid endosperms lag more strikingly than the embryos.	About 3 times as large as hybrids.
At 16-17 day	Outwardly appear normal but somewhat smaller than selfed sibs. The embryo-sac is a larger vacuole. The endosperm is not appreciably larger than at 10 days.	Endosperm and embryo fill the embryo-sac.
At 17-19 day	The embryo-sac collapses and the ovule appears shrunken.	
At 19-21 day	The ovule is discolored and appears dead. Embryo about 0.5 mm. long and is straight.	Ovule about 3 0 mm. long with large cotyledons and is curved.

[4] Unpublished data, Biology Department, University of Saskatchewan.

Hybrid embryos dissected out at an early stage and placed in sterile, nutrient media continued development considerably longer than when they remained in the mother tissue. None of the comparatively few embryos treated in this manner developed to a normal state of maturity, however.

IV. Description of the Hybrid Plants

Hybrid plants resulting from *M. albus* × Redfield Yellow crosses were, without exception, strong vigorous plants. In most characters they occupied a position intermediate between the two parents. This was particularly noticeable in the colour of the flowers which were pale yellow or yellowish white in every instance.

Some of the hybrids were completely fertile. They set seed readily and an examination of the pollen revealed mainly normal well filled grains. Others were partially sterile, setting seed only sparingly and producing a high percentage of sterile pollen grains. All of the hybrids produced ample seed, however, from which to grow reasonably large F_2 progenies.

DISCUSSION

Of the sweet clover species crosses, made in these experiments, only those between *M. albus* and Redfield Yellow parents produced hybrids. Not a single hybrid was obtained from over 7000 *M. albus* × *M. officinalis* crosses, although supposed natural hybrids between these species have been described. The latter, however, were not the result of controlled crosses and it may be that the yellow flowered parents of the hybrids reported by Haussknecht, Kirk and Sylven were ol the same species as Redfield Yellow, probably *M. suaveolens*.

The intergeneric crosses between *Medicago* and *Melilotus* and between *Medicago* and *Trigonella* were likewise unproductive of hybrids as were also those between *Melilotus* and *Trigonella*. The unusually large number of apparent selfs from the latter cross is interesting. The extent to which apomisis may explain these results has yet to be determined. The consistency with which like results were obtained when the crosses were repeated would indicate that they cannot be explained on the basis of faulty technique.

The production of abortive embryos is significant in that it shows that failure to obtain hybrids was not, in many cases, due to the inability of the pollen to effect fertilization but to the death of the embryo some time after fertilization had taken place. The pods containing abortive embryos ceased development in about 10 days after fertilization. They appeared mature and fell from the plant in from 17 to 21 days, whereas normal pods matured in from 30 to 32 days.

The occurrence of numerous abortive embryos from self-fertilized flowers in many inbred lines of *Melilotus*, more especially in those which possess the non-self-pollinating type of flower structure, as well as in *Trigonella* and *Medicago* to a lesser extent, suggests that the phenomena may be fairly common among legumes. The work of Woodworth (*12*) and Halstead (*3*), on soybeans is of interest in this connection.

The possibility of dissecting out the young hybrid embryos while they are still alive and maturing them on a sterile, nutrient medium is being further investigated. While attempts along this line have not been

successful to date it is interesting to note that the embryos which were removed from the parent tissue and treated thus continued to live and develop much longer than when left on the mother plant.

The hybrids obtained from the *M. albus* × Redfield Yellow crosses, and more particularly those from crosses between the new dwarf branching "Alpha" types and Redfield Yellow, appear to possess many useful agronomic characters. The F_2 dwarf branching type plants are much more vigorous than the parent of the same type and in addition they possess many of the desirable characters of the Redfield Yellow parent.

SUMMARY

1. Interspecific hybrids were readily obtained by crossing *Melilotus albus* with a yellow blossom variety of *Melilotus* known as Redfield Yellow. The hybrid plants were strong and vigorous, most of them perfectly fertile, and a few partially sterile. Marked variations in compatibility between different varieties and individual plants of *M. albus* when crossed with Redfield Yellow were observed. Crosses between varieties of *Melilotus officinalis* and Redfield Yellow produced no viable seed but in some cases shrunken seed with abortive embryos were obtained. It would appear that Redfield Yellow is related genetically more closely to *M. albus* than to *M. officinalis*.

2. No viable seed was obtained from *M. albus* × *M. officinalis* crosses, but in most cases abortive embryos were formed showing that fertilization has taken place. Failure to obtain hybrids from the *Melilotus* species crosses was due to the death of the embryo at an early stage in the development of the seed. The direction in which interspecific crosses were made did not appear to have any influence on the production of abortive embryos.

3. Hybrids were not obtained from any of the following intergeneric crosses: *Medicago media* × *Melilotus albus; Medicago media* × *Melilotus officinalis; Medicago media* × *Trigonella coerulea; Melilotus albus* × *Trigonella coerulea; Melilotus officinalis* × *Trigonella coerulea*. No seed was formed when alfalfa was pollinated by sweet clover but abortive seeds were produced in a few cases from the reciprocals of these crosses. All crosses between sweet clover species or alfalfa and *Trigonella coerulea* were fruitless except in the case of *Trigonella* × *M. albus* when the latter was the female parent. This particular mating produced normal seed greatly in excess of the control flowers which were emasculated but not pollinated. The possibility of apomictic development of the seed is being investigated.

4. Seeds with abortive embryos were produced by self-fertilized flowers of *Melilotus*, *Medicago* and *Trigonella*.

ACKNOWLEDGMENTS

Thanks are due to Dr. W. P. Thompson, Biology Department, University of Saskatchewan, for his kindly interest in this work and for making available the data on the development of abortive embryos. In the work of emasculation and pollination the assistance of Mr. Frank Rose is especially acknowledged.

LITERATURE CITED

1. Brink, R. A. Self-incompatibility in yellow sweet clover (*Melilotus officinalis*). Jour. Amer. Soc. Agron. *26* : 307-312. 1934.
2. Dann, Bernhard. Uber die befruchlungsverhaltnisse der bastardluzerne (*Medicago media*) anderer Medicago-arten and steinklee (*Melilotus*). Zeitschrift Fur Zuchtung, Reiche A. Band XV/ heft 4, November 1930

3. HALSTED, B. D. Abortiveness of ovules in connection with position in pod. N.J. Exp. Stn. Ann. Report, pgs. 321-325. 1914.

4. ————————. Abortiveness as related to position in the legumes. Proc. 38th Ann. Meeting, Soc. Prom. Agr. Sci., pgs. 69-73. 1917.

5. HAUSSKNECHT, C. Kleinere Botanische Mitteilungen, Mitt. Bot. Ver. Ges. Thyringen, Baden, Germany 8 Jena. 1890.

6. KIRK, L. E. Natural crossing between white flowered and yellow flowered sweet clover. Sci. Agr. *9* : 313-315. 1929.

7. ————————. Inheritance of flower colour in a cross between white blossom and yellow blossom sweet clover. Sci. Agr. *11* : 265-273. 1931.

8. ————————. Abnormal seed development in sweet clover species crosses—A new technique for emasculating sweet clover flowers. Sci. Agr. *10* : 321-327. 1930.

9. ————————. and T. M. STEVENSON. Factors which influence spontaneous self-fertilization in sweet clover (*Melilotus*). Can. Jour. of Research *5* : 313-326. 1931.

10. LAIBACH, F. Methods and genetic possibilities of propagating embryos otherwise dying in the seed. Jour. Heredity *20* : 201-208. 1929.

11. SYLVEN, NILS. *Melilotus albus* Desr. × *M. officinalis* (L) Desr. funner I Sverige Botaniska Notiser, Lund, 301-304. 1929.

12. WOODWORTH, C. M. Abortive seeds in soybeans. Jour. Amer. Soc. Agronomy, *22* : 37-50. 1930.

Résumé

Etudes de croisements interspécifiques avec le Melilotus et de croisements intergénériques de Melilotus Medicago et de Trigonella. T. M. Stevenson et L. E. Kirk, Laboratoire fédéral des plantes fourragères, Saskatoon, Sask., et Ferme expérimentale centrale, Ottawa, Ont.

On a obtenu facilement des hybrides interspécifiques en croisant *Melilotus albus* avec une variété de *Melilotus* à fleur jaune, connue sous le nom de "Redfield Yellow." Les plants hybrides étaient forts et vigoureux, la plupart d'entre eux tout à fait fertiles, et quelques-uns partiellement stériles. Des variations marquées de compatibilité ont été notées entre les différentes variétés et entre les différentes plantes *de M. albus*, croisées avec le Redfield Yellow. Les croisements effectués entre des variétés de *Melilotus officinalis* et le Redfield Yellow n'ont pas produit de semence viable, mais on a obtenu dans certains cas des semences ratatinées, à embryon abortif. Le Redfield Yellow paraît avoir une parenté génétique plus étroite avec le *M. albus* qu'avec le *M. officinalis*. Les croisements entre *M. albus* et *M. officinalis* n'ont donné aucune semence viable, mais dans la plupart des cas des embryons abortifs se sont formés, montrant qu'il y avait eu fécondation. Si l'on n'a pas réussi à obtenir d'hybrides des croisements effectués entre les espèces de *Melilotus* c'est parce que l'embryon est mort au commencement même du développement de la semence. La direction dans laquelle les croisements interspécifiques ont été faits ne paraît avoir exercé aucun effet sur la production d'embryons abortifs. Aucun hybride n'a été obtenu de l'un ou de l'autre des croisements intergénériques suivants: *Medicago media* x *Melilotus albus; Medicago media* x *Melilotus officinalis; Medicago media* x *Trigonella coerulea; Melilotus albus* x *Trigonella coerulea; Melilotus officinalis* x *Trigonella coerulea*. Aucune graine ne s'est formée lorsque la luzerne était pollinisée par le mélilot, mais les réciproques de ces croisements ont produit, dans quelques cas, des semences abortives. Aucun des croisements entre les espèces de mélilot ou la luzerne et *Trigonella coerulea* n'a donné de produit sauf dans le cas de *Trigonella* x *M. albus* et quand ce dernier était le parent femelle. Ce dernier accouplement a produit de la semence normale en quantité beaucoup plus forte que les fleurs témoins qui avaient été émasculées mais non pollinisées. On étudie actuellement la possibilité du développement apomictique de la semence. Les fleurs auto-fertilisées de *Melilotus*, *Medicago* et *Trigonella* ont produit des semences à embryons abortifs.

BOOK REVIEW

THE GENETICS OF GARDEN PLANTS. M. B. Crane and W. J. C. Lawrence. Toronto: The Macmillan Co. of Canada Ltd. $3.00.

The authors of this book are particularly well qualified for their task of summarizing and presenting in readily understandable form our present knowledge of the genetics of garden and orchard plants. Their joint and several research papers on the genetics and cyto-genetics of horticultural plants are outstanding in that field of work. In addition they know their problems from the point of view of the gardener and the practical grower. The present reviewer being well acquainted with their work expected an outstanding book from them. He is not disappointed.

Considering first the general principles of genetics the authors illustrate their points with well-chosen examples from the crop-plants discussed in detail in the later chapters. The modern viewpoint of the relationship between genes and characters and between the different genes of any genetic complement is summed up in a paragraph which might with great profit be included in every elementary text gook of genetics. "The gene is the unit of reproduction in the hereditary material; and a character the end result of a long and complex chain of reactions which, initiated in the genes, cause the production of the character under favourable environmental conditions . . . . The fact that a gene (which we may denote by the letter D) causes hairs to form on the fruits of the peach must not be taken to mean that this is the only function of D, or that D independently is able to cause hairs to develop. What it does mean, however, is that the gene D is identified by its most conspicuous effect and that if D is absent the effect will not be produced. Thus peaches breed true to downy skin not merely because they contain the gene D but because their germ-cells contain all the genes necessary for the development of the peach character." And again: "From a genetic point of view it is therefore evident that a plant is a double structure derived from the union of two cells carrying similar or dissimilar genes, the identification of which *depends upon the study of differences.*" (reviewer's italics.)

Unfortunately, though stressing initially this broad interpretation of the nature of the gene, the authors have not gone to the length of modernising the nomenclature of some of the workers whom they quote in the later part of the book. A further criticism might be made of their failure to indicate that the interpretations of mitosis and meiosis which they present are inacceptable in matters of detail to many cytologists. True, they are presenting only an elementary outline of these processes, and they have offered that which is simplest and most concise, but the elements of theory and of generally accepted observation which are involved might have been differentiated.

The chapters presenting the genetics of special crops give in concise form practically all the data available in many cases. The sections on strawberries and pome fruits are particularly good. That on grapes is, however, inadequate. The chapters on incompatibility and sterility, in which the authors have made outstanding original contributions, are very clear presentations of a complex set of problems. The exposition of polyploidy and the discussion of the various means by which new and improved forms of plants originate are well-balanced conservative statements of the extent of our present knowledge. The origin and nature of chimaeras are clearly and concisely explained, and their practical significance is indicated.

Apart from the points cited above and a few minor details of terminology, this book is admirable both as a readily uuderstandable exposition of general genetic principles and as a special reference to the genetics of garden and orchard plants. Undoubtedly it should be read, and kept handy for reference, by every plant breeder and every progressive practical flower, fruit, or vegetable grower or nurseryman.

C. L. HUSKINS.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index number of wholesale prices of 567 commodities advanced from 71.5 in January to 72.0 in February, the highest point reached since June of last year but fractionally lower than in February 1924. Gains were registered in the indexes of vegetable products and animals and their products. The changes in indexes of other sub-groups were not large. Canadian farm products were higher in price, the index rising from 61 4 to 62.0. The index of prices of grain was unchanged at 55.7 but that for animal products rose from 71 0 to 72 6 in February. Retail prices and costs of services were slightly higher, the index being 78 9. Food prices were slightly higher, the index being 69 2 compared with 68 8 in January and 69.3 in December.

Physical Volume of Business.—The index of the physical volume of business reached 100 6 in February. This was the highest point registered in several years and slightly above the index in the base year 1926 It represented a gain of over 3 points compared with that for January. The index of industrial production rose from 97 8 to 101 1, gains in shipments of nickel, copper, silver and gold were fairly substantial. In the manufacturing group, the index advanced from 88 9 to 92.5. Food stuffs contributed the largest gain A little less activity was shown in the forestry group though output of newsprint and exports of wood and wood pulp and shingles were substantially above the figures for January. A bright spot was the advance in iron and steel production. Automobile production again made a very substantial gain from 73 8 to 104 6. Construction too was somewhat higher than in the month of January, the index rising from 73 4 to 76 9, an increase in building permits being entirely responsible. Trade employment was slightly higher and car loadings were also above the figure for January. Grain and live stock marketings rose from 30 6 to 62 2. Grain marketings advanced from 19 3 to 55 2. Larger shipments of wheat, oats and barley were responsible for the improvement. Live stock marketings rose from 81 5 to 93 4. Very large increases in the marketing of cattle and sheep, a slight increase in shipments of calves and a fairly large increase in hog marketings characterized the movement of live stock during February.

A feature of the live stock situation has been the resumption of trade in cattle with the United States Up to April 5th, 31,565 head had been shipped across the line compared with 872 in the same period a year ago. Exports to Great Britain have, however, been substantially below those of a year ago. Cold storage holdings were slightly lower than at Januray 1st. Reduced stocks of butter, pork and lard caused the reduction.

Prices in United States.—With the exception of cotton and grain, prices of farm products in the United States have continued to rise. The February index of prices of grain was 114 compared with 115 in January. The index of cotton was unchanged at 108. The index prices of fruit advanced 2 points to 89. In the case of truck crops, the index rose from 117 to 188. That for meat animals advanced from 96 to 105. Dairy products showed a gain of 9 points the index being 121 in February. Chickens and eggs advanced from 114 to 119 and all groups from 107 to 111. The index of prices paid by farmers f r commodities bought rose from 126 to 127 and the ratio of prices received to prices paid advanced from 85 to 87. These data are taken from the Agricultural Situation published by the Bureau of Agricultural Economics at Washington.

Prices in Great Britain.—The index of prices of bacon pigs was 120 in February 1935 compared with 129 in February 1934. Pork was 125 and 135 respectively. Dairy cows were 102 and 101. Store cattle 84 compared with 92. Poultry

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62 6	56 4	77 0	65.4				
1914	65 5	69 2	64 9	79.0	66 0				
1915	70.4	77 7	76.9	79 2	67 3				
1916	84.3	89 7	88 4	92 3	72.5				
1917	114.3	130 0	134 3	119 6	85 6				
1918	127.4	132.9	132 0	134.7	97 4				
1919	134.0	145.5	142 4	152 5	107 2	71 3	65.5	48.1	47.1
1920	155.9	161 6	166.5	149.9	124 2	75 0	69 9	52.6	94.2
1921	110.0	102 8	100.3	108 5	109 2	66 5	60 4	65.2	86 4
1922	97 3	86 7	81.3	99.1	100 0	79 1	76.9	82.6	82 8
1923	98.0	79 8	73.3	95 1	100 0	85.5	83 8	91 4	87.6
1924	99.4	87.0	82 6	97 2	98 0	84 6	82 4	102 5	114.9
1925	102 6	100 4	98 1	105.7	99 3	90 9	89 7	97 2	108.6
1926	100.0	100.0	100 0	100 0	100 0	100.0	100 0	100 0	100 0
1927	97.7	102.1	99 9	105 7	98 4	106 1	105.6	103 6	110.0
1928	96.4	100.7	92.6	114 3	98 9	117.3	117 8	146.7	112.8
1929	95.6	100 8	93 8	112 5	99 9	125.5	127 4	101 1	109.6
1930	86.6	82.3	70 0	102 9	99 2	109 5	108.0	103.0	128.4
1931	72 2	56.3	43 6	77.6	89.6	93 5	90 4	99 0	125.7
1932	66 7	48 4	41 1	60.7	81 4	78.7	74.0	114.3	120.1
1933	67 1	51 0	45.8	59.6	77 7	79.7	76.8	105.1	115.4
1934	71 6	59 0	53.9	67.6	78.9	94.2	93.6	88.5	114.2
1934									
Jan.	70.6	55 3	47 9	67 8	78 2	86 8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72 5	78 7	86 4	84.0	67 1	98.6
Mar.	72 0	56.5	49.5	68.3	79.9	93 1	92.0	63.8	97.0
Apr.	71.1	55 4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56 9	51.1	66.5	78 5	99.6	99.4	130 6	102.6
June	72.1	59.3	55 5	65 6	78 2	95 8	95 2	97.2	126.1
July	72.0	60 0	57.8	63 7	78.4	95.7	95 6	148.8	116.3
Aug.	72.3	61 6	60.7	63 1	78.7	99 0	99 8	172 8	114.7
Sept.	72.0	61.3	58.9	65.3	79 0	97.1	97 5	127.7	117.7
Oct.	71.4	60 9	55 3	70.4	79 3	95.8	95.3	61.2	128.8
Nov.	71.2	61.2	55.7	70.4	79.4	96.5	97 0	51.2	130.4
Dec.	71 2	61.6	56 0	70.9	79.0	92.4	91.0	36 0	135.7
1935									
Jan.	71.5	61.4	55.7	71 0	78.9	96 5	96 3	30 6	143.7
Feb.	72 0	62 0	55 7	72 6	79 1	100.6	101 1	62 2	141 7

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1933, p. 15.
2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1933, p. 33, and Monthly Mimeographs 1934 and 1935.
3. Wholesale prices of grains, fruits and vegetables.
4. Wholesale prices of Animals and Animal Products.
5. Including foods, rents, fuel, clothing and sundries, See Prices and price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.

Prices and Price Indexes 1913-1931, p. 108, and Monthly Mimeographs 1934-1935.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

showed a gain of 6 points, the index in February this year being 124. Butter prices were unchanged at 86. Prices of cheese were considerably lower, the index in February 1935 being 94 as against 115. Potatoes were 166 compared with 100 a year ago but had been much higher in November and December with the index at 121 in January of this year. Prices of wool were considerably below those of February 1934. The total index was 115 in February compared with 117 in the previous month.

Farm Land Values.—The value of farm lands in Canada declined to $23 per acre in 1934. During the previous two years it was estimated at $24, whereas in 1929 it was $37, and in 1920 reached the high point of $48 per acre. The values reported by provinces showed that occupied farm lands in New Brunswick have the lowest average value of $24 per acre, whereas in British Columbia land values averaged $60 per acre. It is rather interesting to observe that the values reported in Prince Edward Island were $34 per acre last year compared with $32 per acre in 1933. Similarly, in Nova Scotia farm land was valued at $27 in 1934 compared with $26 in the previous year. Values in New Brunswick were unchanged. In Quebec on the other hand, a decline of $2 per acre was reported, the average in 1934 being given as $34. In the Province of Ontario farm lands increased to $41 compared with $38 in 1933. In Manitoba values were reported to be $1 higher at $17 per acre. There was no change in Alberta and a decline of $3 per acre in British Columbia. Orchard lands in Nova Scotia, Ontario, and British Columbia are reported separately.

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE, OTTAWA, PRINCIPALEMENT D'APRÈS LES DONNÉES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

Le chiffre indice des prix de gros de 567 produits, après avoir atteint 71 5 en janvier, est monté à 72.0 en février; c'est le plus haut point qu'il ait atteint depuis juin l'année dernière, mais il est encore d'une fraction plus bas qu'en février 1934. Des augmentations ont été enregistrées dans les indices des produits végétaux et des animaux et leurs produits. Les changements notés dans les indices d'autres sous-groupes ne sont pas considérables. Les prix des produits de la ferme canadiens ont monté, l'indice passant de 61 4 à 62 0. L'indice des prix du grain est resté au même point, à 55 7, mais celui des produits animaux s'est élevé de 71 0 à 72.6 en février. Les prix du détail et les frais des services étaient un peu plus élevés, l'indice atteignant 78 9. Les prix des denrées alimentaires étaient aussi un peu plus élevés, l'indice étant de 69 2 contre 68 8 en janvier et 69 3 en décembre.

Volume physique des affaires.—L'indice du volume physique des affaires a atteint 100.6 en février, c'est le plus haut point qui ait été enregistré depuis plusieurs années; il est légèrement supérieur à l'indice de l'année de base 1926. Il représentait un gain de plus de 3 points sur celui de janvier. L'indice de la production industrielle s'est élevé de 97 8 à 101 1, les augmentations notées dans les expéditions de nickel, de cuivre, d'argent et d'or étaient assez considérables. Dans le groupe des produits manufacturés, l'indice est passé de 88 9 à 92 5. Ce sont les produits alimentaires qui ont fourni la plus forte augmentation. Le groupe forestier manifestait un peu moins d'activité, quoique la production de papier à journal et les exportations de bois de pulpe et de bardeaux fussent bien supérieures au chiffre de janvier. Un trait réjouissant est la hausse enregistrée dans la production du fer et de l'acier; la production des automobiles a encore enregistré une très forte augmentation, passant de 73 8 à 104 6. L'industrie du bâtiment était aussi à un niveau un peu plus élevé qu'en janvier, l'indice passant de 73.4 à 76 9; cette amélioration est due entièrement à une augmentation dans le nombre de permis de construction. Le nombre d'employés dans le commerce était un peu plus élevé et les chargements de wagons étaient également supérieurs au chiffre de janvier. Les ventes de grain et de bestiaux ont passé de 30 6 à 62 2. L'augmentation pour les ventes de grain seules a été de 19 3 à 55 2 en raison des expéditions plus fortes de blé, d'avoine et d'orge. Les ventes de bestiaux ont passé de 81 5 à 93 4. Le commerce des bestiaux en février s'est signalé par de très fortes augmentations dans les ventes de bovins adultes et de moutons, une légère augmentation dans les expéditions de veaux et une assez forte augmentation dans les ventes de porcs.

Un trait spécialement à signaler dans la situation du bétail est la reprise du commerce des bovins avec les Etats-Unis. Jusqu'au 5 avril il s'était expédié 31,565 animaux de l'autre côté de la frontière contre 872 pendant la même période l'année dernière. Quant aux exportations en Grande-Bretagne elles ont été bien inférieures à celles d'il y a un an. Les stocks de produits en entrepôt étaient un peu inférieurs à ceux du 1er janvier. Cette réduction portait principalement sur le beurre, le lard et le saindoux.

Prix aux Etats-Unis.—A l'exception du coton et du grain, les prix des produits de la ferme aux Etats-Unis ont continué à augmenter. L'indice du prix du grain en février était de 114 contre 115 en janvier. L'indice du coton est resté au même point à 108. L'indice des prix des fruits est monté de 2 points, à 89. En ce qui concerne les récoltes maraîchères, l'indice a passé de 117 à 188, celui des animaux à viande de 96 à 105. Les produits laitiers accusaient un gain de 9 points, l'indice étant de 121 en février. Les poulets et les œufs ont passé de 114 à 119 et tous les

groupes de 107 à 111. L'indice des prix payés par les cultivateurs pour les marchandises achetées est monté de 126 à 127 et la relation entre les prix reçus et les prix payés s'est élevée de 85 à 87. Ces données sont extraites de la "Situation agricole" publiée par le Bureau de l'économie agricole à Washington.

Prix en Grande-Bretagne.—L'indice des prix des porcs à bacon était à 120 en février 1935 contre 129 en février 1934. Le porc était à 125 et 135 respectivement. Les vaches laitières étaient à 102 et 101. Les bœufs d'engrais à 84 contre 92. Les volailles accusaient un gain de 6 points, l'indice de février cette année étant de 124. Les prix du beurre sont restés au même point, à 86. Les prix du fromage étaient beaucoup plus bas, l'indice de février 1935 étant de 94 contre 115. Les pommes de terre étaient à 166 contre 100 l'année dernière, mais elles avaient été beaucoup plus élevées en novembre et en décembre, l'indice était à 121 en janvier de cette année. Les prix de la laine étaient bien inférieurs à ceux de février 1934. L'indice total était à 115 en février contre 117 en janvier.

Valeur des terres arables.—La valeur des terres arables au Canada était de $23 par acre en 1934. Pendant les deux années précédentes, elle avait été estimée à $24, tandis qu'en 1929 elle était à $37, et en 1920 elle avait atteint le chiffre élevé de $48 par acre. Les valeurs signalées par les provinces montrent que les terres arables occupées au Nouveau-Brunswick sont celles qui ont la plus faible valeur moyenne, savoir, $24 par acre, tandis qu'en Colombie-Britannique cette valeur était en moyenne de $60 par acre Un fait intéressant à noter c'est que la valeur enregistrée dans l'Ile du Prince-Edouard était de $34 par acre l'année dernière contre $32 par acre en 1933. De même, en Nouvelle-Ecosse, la terre arable était évaluée à $27 en 1934 contre $26 l'année précédente. Au Nouveau-Brunswick, il n'y a pas eu de changement dans la valeur. Par contre, dans le Québec, on signale une diminution de $2 par acre, la moyenne en 1934 était de $34. Dans la province de l'Ontario, la valeur des terres arables est montée à $41 contre $38 en 1933. Au Manitoba elle a remonté de $1, soit $17 par acre. Il n'y a pas eu de changement dans l'Alberta tandis que l'on enregistrait une baisse de $3 par acre en Colombie-Britannique. Les terres en vergers dans la Nouvelle-Ecosse, l'Ontario et la Colombie-Britannique sont l'objet d'un rapport séparé.

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SMOOTH-AWNED BARLEY VARIETIES[1]

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INTRODUCTION

Within the last decade a number of approved smooth-awned varieties of barley have become available to American and Canadian farmers. Prior to 1912 breeding work with bearded varieties was confined to the selection and crossing of rough-awned sorts. Although a number of excellent types were developed, they possessed the objectionable barbed awns. The substitution of hooded and hulless types for bearded forms did not prove altogether satisfactory, as the former were generally inferior in yielding capacity and tended to shatter readily.

Investigators have shown that the awns of the barley spike are important as transpiratory organs (*7*, *8*, *12*). Zoebl and Mikosch, cited by Hayes and Wilcox (*12*), worked with both two- and six-rowed barley and compared the transpiration rate of awned spikes and spikes with awns removed. They found the normal spikes to give off four to five times more water than the spikes with the awns removed. Perlitius, also cited by Hayes and Wilcox (*12*), found that transpiration was reduced 75% in the case of barley when awns were removed. Harlan and Anthony (*7*) found that, in addition to serving as transpiratory organs, the awns of barley serve as a depository for minerals. These investigators compared the daily development of clipped spikes with that of normal spikes. The awns of the normal spikes were found to contain 30% ash at maturity. In the case of clipped spikes the extra ash materials were probably deposited in the rachis. This deposition of ash caused the spikes to become brittle and prone to breaking. They believed their results could be used to explain the characteristic brittleness of the spikes of hooded and awnless barley varieties. Hayes and Wilcox (*12*) found that smooth-awned barleys were not handicapped physiologically in so far as transpiration capacity was concerned.

In wheat, certain workers have reported positive, others negative, and still others no relationship existing between the presence of awns and grain yield (*3*).

Harlan (*6*) first pointed out the economic advantages of smooth-awned varieties of barley. He believed that rough awns had limited the production of the barley crop, both through the added inconvenience they cause during harvesting and threshing, and their injurious nature when

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the straw is fed to livestock. Harlan (*6*) must also be credited for initiating the first smooth awn barley breeding programme in America.

VARIETAL TESTS

The breeding of smooth-awned barleys was greatly stimulated in the years 1913–17, when two black, smooth-awned varieties imported from Russia were distributed to different experiment stations in the United States and Canada, by the Office of Cereal Investigations, United States Department of Agriculture (*6*). As a result of this early work several experiment stations have now introduced smooth-awned barley varieties comparing favourably in agronomic characteristics with the more improved rough-awned sorts.

In the smooth awn barley breeding work at the Minnesota Experiment Station special attention was given to the selection of strains resistant to the spot blotch disease caused by *Helminthosporium sativum* (*11, 13*). As a result, that station has introduced several smooth-awned varieties, including the well-known Glabron, Velvet and Comfort varieties which are resistant to this disease (*11*). The Michigan station has developed a smooth-awned, two-rowed, stiff-strawed variety known as Spartan (*5*). Resistance to the stripe disease caused by *Helminthosporium gramineum* has been combined with smooth awn in the variety Wisconsin Barbless No. 38, introduced by the Wisconsin Agricultural Experiment Station (*17*). The University of Saskatchewan at Saskatoon, Saskatchewan, has developed the variety Regal, from selections received from the Minnesota Experiment Station (*9*). It has a stiff straw and appears to be especially well adapted to Saskatchewan conditions.

The University of Alberta at Edmonton, Alberta, is at the present time increasing seed for distribution of a smooth-awned hybrid selection named Newal (H-19-146), which has shown great promise in recent varietal trials (*1*). This variety was developed from a cross made in 1919 between a white, six-rowed, smooth-awned selection (from a Manchurian × Lion cross) obtained from the Minnesota Agricultural Experiment Station, and a six-rowed rough-awned variety, O.A.C. No. 21. The latter is probably the most widely grown six-row barley variety in western Canada, and is generally favored by maltsters (*10*).

The above mentioned smooth-awned barley varieties have been included in barley varietal tests conducted at the University of Alberta for the period 1930–34. Data have been gathered on yield, earliness, strength of straw, height, weight per bushel and disease reaction. Each of these characters will be discussed in detail.

All of the regular varietal tests were conducted in systematically distributed quadruplicated rod-row plots. Each plot consisted of three rows one foot apart. The ends of the rows were trimmed off before harvest. The grain from the centre row was used for yield determinations and that from the border rows for malting tests.

Yield

Three of the recommended varieties for Alberta were included in the test for comparison. These were Trebi and O.A.C. No. 21, six-rowed, rough-awned varieties, and Canadian Thorpe, a rough-awned, two-rowed variety.

The available yield data for the five-year period 1930–1934 are summarized in Table 1. Both the four-year and five-year averages have been expressed as a percentage of the yield of O.A.C. No. 21. Newal shows the highest averages of the smooth-awned varieties tested, and outyields O.A.C. No. 21 by 8% for the five-year period. Comfort and Regal compare favourably with O.A.C. No. 21, yielding in the four-year average (1930–33) 97 and 95% of the latter respectively. Glabron, Velvet and Spartan are distinctly inferior in yielding capacity to O.A.C. No. 21. Spartan, a two-rowed, smooth-awned barley yielded several bushels less than the rough-awned, Canadian Thorpe. For the 1932-33 period Wisconsin Barbless No. 38 appears to rank with Comfort and Regal in yielding capacity.

Owing to the popularity of the smooth-awned type of barley and the demand for definite information regarding suitability to various parts of the country, arrangements were made by the Cereal Division of the Central Experimental Farm, Ottawa, and the National Barley Committee, in the spring of 1934, for a co-operative barley nursery at Edmonton to test

TABLE 1. COMPARATIVE YEARLY (1930–34) AND AVERAGE YIELDS OF ROUGH- AND SMOOTH-AWNED VARIETIES WHEN GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Yield in bushels per acre								
		1930	1931	1932	1933	1934	4-year* average 1930–33	4-year average in % of O.A.C. No. 21	5-year† average 1930–34	5-year average in % of O.A.C. No. 21
O.A.C. No. 21	734	36.5	56.8	50.5	44.7	66.5	47.1	100	51.0	100
Trebi	753	32.7	54.9	59.1	37.5	78.0	46.0	98	52.2	102
Canadian Thorpe	816	11.0	50.0	44.5	34.8	40.0	35.1	75	36.1	71
Comfort	712	35.8	52.4	47.4	47.1	—	45.7	97	—	—
Glabron	718	29.0	49.3	43.4	39.5	50.2	40.3	86	42.6	84
Newal	1089	43.5	63.9	53.2	40.7	73.5	50.3	107	55.0	108
Regal	742	34.7	54.9	46.6	42.9	67.5	44.8	95	49.3	97
Spartan	860	22.5	43.9	33.4	31.5	49.0	32.8	70	36.1	71
Velvet	755	22.0	52.4	41.3	42.9	—	39.7	84	—	—
Wisconsin Barbless No. 38	758	—	—	48.9	41.5	—	—	—	—	—

*Standard error of the mean yield of a single variety for the four-year period, 1930-33, is 1.76 bushels. Significant difference between the means of any two varieties is 5.29 bushels.

†Standard error of the mean yield of a single variety for the five-year period, 1930–34, is 1.61 bushels. Significant difference between the means of any two varieties is 4.83 bushels.

the smooth-awned barley varieties, together with a few of the standard rough-awned sorts. In these tests the quadruplicated plots were distributed at random, but in all other respects were handled similarly to the regular varietal test plots. In Table 2 is given a summary of the data obtained from these co-operative smooth awn nursery tests.

With regard to yield, it will be seen that Newal exceeded all other varieties under test. The standard error of the mean of a single variety for this experiment was 4.75 bushels. Hence varietal differences exceeding three times this figure, or 14.25 bushels, may be judged significant. On this basis Newal significantly exceeds all varieties with the exception of Trebi. Regal shows significant increases over Comfort, Glabron and velvet, but does not significantly exceed Wisconsin Barbless No. 38.

Earliness of Maturity

Earliness of maturity is an important characteristic of any variety developed for northerly regions. It has an added significance in the case of barley, since this cereal is often sown late as a cleaning crop. From the data given in Table 3 it will be seen that there is little difference in the matter of earliness between the smooth-awned varieties tested. On the basis of the four-year (1930-33) average a spread of only three days exists

TABLE 2.—SUMMARY OF DATA FROM THE CO-OPERATIVE SMOOTH AWN BARLEY NURSERY AT THE UNIVERSITY OF ALBERTA, EDMONTON, 1934

Variety	Canadian accession number	Growth period in days	Percentage lodged	Height in inches	Weight per bushel in pounds	Average yield* in bushels per acre
Brandon 1099	1106	90	29	45	49.5	66.5
Brandon 2131	1110	90	11	46	49.0	58.5
Comfort	1107	90	16	49	45.5	56.5
Glabron	1093	88	6	48	50.0	56.5
Hannchen	1109	89	22	39	55.0	62.5
Newal	1089	85	3	45	52.0	88.0
Nobarb	1022	91	17	43	51.0	61.5
O.A.C. No. 21	1086	86	10	48	48.0	70.0
Ottawa 1014 E.25	1105	84	17	46	48.5	49.0
Regal	742	89	7	45	51.5	73.0
Sanalta	1088	91	4	44	52.0	70.0
Sans Barb 2	1074	87	19	45	48.5	71.5
Sans Barb 3	746	97	52	42	48.0	56.5
Trebi	1108	87	14	41	45.5	82.0
Velvet	1102	87	12	47	47.5	56.5
Wisconsin Barbless No. 38	1101	90	21	47	47.5	60.0

*Standard error of the mean of a single variety computed by the analysis of variance method = 4.75 bushels. The significant difference between the means of two varieties is 14.25 bushels.

TABLE 3.—COMPARATIVE YEARLY (1930–34) AND AVERAGE GROWTH PERIODS OF ROUGH- AND SMOOTH-AWNED VARIETIES OF BARLEY, GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Growth period in days*								
		1930	1931	1932	1933	1934	4-year average 1930-33	No. of days + or − O.A.C. No. 21 4-year av.	5-year average 1930-34	No. of days + or − O.A.C. No. 21 5-year av.
O.A.C. No. 21	734	84	104	82	77	85	87	0	86	0
Trebi	753	85	109	84	77	87	89	+2	88	+2
Canadian Thorpe	816	93	106	89	85	97	93	+6	94	+8
Comfort	712	88	108	86	78	–	90	+3	–	—
Glabron	718	85	107	85	78	88	89	+2	89	+3
Newal	1089	86	106	84	77	86	88	+1	88	+2
Regal	742	87	104	85	78	88	89	+2	88	+2
Spartan	860	80	105	86	77	90	87	0	88	+2
Velvet	755	85	105	85	78	–	88	+1	—	—
Wisconsin Barbless No. 38	758	–	–	85	82	–	—	—	—	—

*Growth period is the number of days from emergence of seedlings to maturity.

between the earliest variety, Spartan, and the latest, Comfort. As Spartan is equal in average growth period with O.A.C. No. 21 and two days earlier than Trebi, it is evident that the smooth-awned varieties as a group compare favourably with the rough-awned varieties Trebi and O.A.C. No. 21 in earliness of maturity. Canadian Thorpe is, however, 6 days later than Spartan. The five-year averages (1930-34) show the varieties Newal, Regal and Spartan to be equal in growth period with Trebi and only two days later than O A.C. No. 21. Glabron averaged three days later than the latter.

In the smooth-awned co-operative nursery at Edmonton in 1934 there was a difference between the earliest and latest maturing varieties of 13 days (See Table 2). Ottawa 1014 matured in 84 days and Newal in 85 days, while Sans Barb No. 3 required 97 days. It will be noted that the rough-awned varieties O.A.C. No. 21 and Trebi required respectively 86 and 87 days.

Strength of Straw

Strength of straw is of great importance in a barley variety. Not only is the yield of a lodged field greatly reduced, but the difficulties of harvesting are increased. The data in Table 4 show the comparative lodging of the varieties grown in the test. Percentage lodging was calculated by multiplying the percentage of plants lodged by the degrees off the vertical and dividing the product by 90. All of the smooth-awned varieties tested show a more desirable strength of straw than the rough-awned, six-rowed

TABLE 4 – COMPARATIVE YEARLY (1931–34) AND AVERAGE LODGING OF ROUGH- AND SMOOTH-AWNED VARIETIES OF BARLEY GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Lodging in per cent					
		1931	1932	1933	1934	Average 1931–33	Average 1931–34
O A C. No. 21	734	32	1	14	5	16	13
Trebi	753	52	1	5	14	19	18
Canadian Thorpe	816	0	1	0	0	0	1
Comfort	712	8	1	4	—	4	—
Glabron	718	14	0	2	6	5	6
Newal	1089	19	0	2	5	7	7
Regal	742	22	0	1	8	8	8
Spartan	860	2	0	1	3	1	2
Velvet	752	19	1	4	—	8	—
Wisconsin Barbless No. 38	758	—	1	4	—	—	—

varieties O.A.C. No. 21 and Trebi. Spartan appears to possess a particularly stiff straw and compares favourably in this respect with Canadian Thorpe. Comfort and Glabron show perhaps slightly less lodging on the three-year average (1931–33) than Regal, Velvet or Newal.

In the co-operative test in 1934 there were marked differences in lodging (Table II). Newal, Sanalta, Glabron and Regal were only slightly lodged, Sans Barb No. 3 badly lodged and the balance of the varieties only moderately so.

Height of Plant

Generally the length of straw of a barley variety is not considered an important character provided it is not so short as to complicate harvesting. Since the straw of the smooth-awned barleys will in all probability be used to a greater extent as greenfeed than has been the case with rough-awned varieties, a good length of straw consistent with good strength would be a desirable feature. The smooth-awned varieties under discussion all possess a satisfactory length of straw (Table 5). For the period 1930–33, Glabron and Velvet were equal to O.A.C. No. 21, while Newal, Regal and Spartan averaged from two to three inches shorter. Trebi averaged five inches shorter than O.A.C. No. 21 for the same period. From the summarized data obtained from the co-operative test in 1934, it is evident that a similar relationship exists (Table 2.)

TABLE 5.—COMPARATIVE YEARLY (1930–34) AND AVERAGE HEIGHTS OF ROUGH- AND SMOOTH-AWNED BARLEYS GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Height in inches								
		1930	1931	1932	1933	1934	4-year average 1930–33	No. of inches + or − O.A.C. No. 21 for 4-year average 1930–33	5-year average 1930–34	No. of inches + or − O.A.C. No. 21 for 5-year average 1930–34
O.A.C. No. 21	734	32	44	40	37	47	38	0	40	0
Trebi	753	32	41	31	26	41	33	−5	34	−6
Canadian Thorpe	816	28	48	44	30	43	38	0	39	−1
Comfort	712	30	42	40	34	-	37	−1	--	--
Glabron	718	32	44	44	34	50	38	0	41	+1
Newal	1089	29	40	38	33	47	35	−3	37	−3
Regal	742	27	40	41	31	46	35	−3	37	−3
Spartan	860	32	42	38	31	43	36	−2	37	−3
Velvet	755	31	43	43	36	–	38	0	–	-
Wisconsin Barbless No 38	758	–	-	41	35	–	–	—	—	—

Weight per Bushel

A high weight per bushel is to be desired in a barley variety as it denotes plumpness of kernel and a low percentage of hull. From the data given in Table 6 it is evident that all the six-rowed, smooth-awned varieties tested, with the possible exception of Wisconsin Barbless No. 38, show satisfactory weights per bushel as compared with O.A.C. No. 21 and Trebi. From the available data Wisconsin Barbless appears to be slightly inferior in this respect.

Newal ranked highest in weight per bushel of the six-rowed varieties tested. For the four-year period 1931–34 this variety averaged 51 pounds per bushel, as compared with 48.5 and 47.5 pounds shown by O.A.C. No. 21 and Trebi, respectively. It is of interest to note that Newal equalled the two-rowed Canadian Thorpe in this regard. Glabron and Regal both averaged 50 pounds per bushel, or one pound less than Newal.

The two-rowed, smooth-awned variety, Spartan, exceeded Canadian Thorpe by one and a half pounds on the four-year average.

The exceptionally high weight per bushel of Newal is again demonstrated by the results of the co-operative test (Table 2). In this test, Newal possessed the highest weight per bushel of the six-rowed varieties. With the exceptions of Comfort, Velvet and Wisconsin Barbless No. 38, all smooth-awned varieties tested either equalled or exceeded O.A.C. No. 21 in weight per bushel. Comfort showed a weight of only 45.5 pounds as compared with 48 pounds in the case of O.A.C. No. 21. Velvet and Wisconsin Barbless No. 38 each weighed 47.5 pounds per bushel.

TABLE 6.—COMPARATIVE YEARLY (1930-34) AND AVERAGE WEIGHTS PER BUSHEL OF ROUGH- AND SMOOTH-AWNED VARIETIES OF BARLEY GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Pounds per bushel						
		1930	1931	1932	1933	1934	3-year average 1931-33	4-year average 1931–34
O.A.C. No. 21	734	54.0	47.5	52.5	46.5	46.8	49.0	48.5
Trebi	753	50.0	44.0	51.5	46.0	47.5	47.0	47.5
Canadian Thorpe	816	—	53.0	54.0	47.0	50.5	51.5	51.0
Comfort	712	54.5	47.5	53.5	48.5	—	49.5	—
Glabron	718	54.0	47.0	52.5	49.0	51.0	49.5	50.0
Newal	1089	54.5	48.0	54.0	50.5	51.0	51.0	51.0
Regal	742	52.5	47.0	53.5	48.5	50.5	49.5	50.0
Spartan	860	—	52.5	54.0	51.5	52.0	52.5	52.5
Velvet	755	—	48.5	51.5	47.5	—	49.0	—
Wisconsin Barbless No. 38	759	—	—	50.5	45.5	—	—	—

Disease Reaction

Most varieties of barley are susceptible to one or more of the important diseases which affect the barley crop. The well-known rough-awned variety Trebi, which shows resistance to the stripe disease (*H. gramineum*) (*4*), is susceptible to the spot blotch disease (*H. sativum*) and the covered smut disease (*Ustilago hordei*) (*2, 18*). Hannchen and Canadian Thorpe exhibit considerable susceptibility to covered smut (*2*). Peatland, resistant to certain forms of rust (*16*), and Manchuria, resistant to spot blotch (*18*), are both susceptible to the stripe disease (*4*). Peatland is also moderately susceptible to covered smut (*2*). Smooth-awned varieties are no exception with regard to disease reaction. Some of the most promising varieties show susceptibility to a number of the common barley diseases. Thus, Newal and Comfort show considerable susceptibility to the covered smut disease (*2*), while Velvet is highly susceptible and Glabron moderately susceptible to the stripe disease (*4*). Furthermore, investigators generally have noted that smooth-awned varieties are susceptible to the loose smut disease. Both Regal and Wisconsin Barbless No. 38 have been reported as being susceptible to this disease (*9, 17*).

In view of these observations, it is evident that there exists a need for co-ordinating work on smooth awn with that of disease resistance in order to insure obtaining the most desirable strains. Working on this

basis, the Minnesota Agricultural Experiment Station has introduced the varieties Glabron, Velvet and Comfort in which smooth awn has been combined with resistance to the spot blotch disease (*H. sativum*) (*11*, *13*). Similarly, resistance to the stripe disease (*H. gramineum*) has been incorporated into the variety Wisconsin Barbless No. 38, by workers at the Wisconsin Agricultural Experiment Station (*17*).

In both varietal and breeding investigations with smooth-awned barleys, conducted at the University of Alberta, the problem of disease resistance has been a prime consideration. Both covered smut and stripe reaction were studied in a cross involving a smooth-awned variety as one parent (*14*, *15*). Later generations of smooth-awned, resistant selections obtained from this cross are now being compared with standard varieties.

From the results of covered smut tests conducted during the years 1931, 1932, and 1934, Glabron, Velvet and Wisconsin Barbless No. 38 appear to be highly resistant, Regal and Spartan moderately resistant and Newal and Comfort moderately susceptible (*2*).

In 1930, the spikes of a number of barley varieties were dusted at flowering time with chlamydospores of the loose smut fungus (*Ustilago nuda*). The inoculated spikes were enclosed in glassine bags after inoculation and sprayed at intervals with a spore suspension of the fungus. The inoculated seed was sown in the spring of 1931. The infection percentages of the smooth-awned varieties tested are given in Table 7.

TABLE 7. —REACTION OF SIX SMOOTH-AWNED VARIETIES OF BARLEY TO INFECTION WITH THE LOOSE SMUT AND STRIPE DISEASES

Variety	Canadian accession number	Percentage of plants infected			
		Loose smut	Stripe		
		1931	1931	1932	Average
Comfort	712	9	2	3	3
Glabron	718	3	7	0	4
Newal	1089	11	0	0	0
Regal	742	3	9	0	5
Spartan	860	3	0	0	0
Velvet	755	2	24	17	20

Infection was generally low, the only varieties showing even moderate susceptibility being Comfort and Newal. However, observations of natural infections occurring in the varietal plots for the period 1931–34, showed that all of the smooth-awned varieties under discussion were generally susceptible to this disease.

The infection percentages of stripe disease observed on these varieties in the years 1931 and 1932 are also contained in Table 7. The varieties in question were sprayed several times at flowering with a wet conidial suspension of the stripe organism. While the infection percentages are low, the susceptibility of Velvet to this disease is evident. The infection percentages obtained in 1931 show Glabron and Regal to be somewhat susceptible. No infected plants were found in the varieties Newal and

Spartan. Glabron showed infection percentages ranging from 5–25% when used as a parent in the breeding studies referred to above (*15*).

SUMMARY

Data are presented on the agronomic behavior and disease reaction of a number of promising smooth-awned varieties of barley grown at the University of Alberta, Edmonton, for the five-year period, 1930–34. Generally the smooth-awned barley varieties compared quite favourably with the rough-awned varieties O.A.C. No. 21 and Trebi. The smooth-awned varieties as a group possessed a much stronger straw than the latter, and equalled them in length of straw and earliness of maturity.

In yield and weight per bushel, Newal ranked highest of the smooth-awned, six-rowed varieties tested, and also excelled O.A.C. No. 21 and Trebi in these respects. Comfort and Regal compared quite favourably with O.A.C. No. 21 in yielding capacity and weight per bushel. Glabron and Velvet proved to be inferior to the other six-rowed, smooth-awned varieties tested in yielding capacity but showed satisfactory weights per bushel. From the limited data available, Wisconsin Barbless No. 38 appeared to rank with Comfort and Regal in yielding capacity. This variety, however, possessed the lowest weight per bushel of the varieties tested.

The two-rowed, smooth-awned variety, Spartan, possessed an exceptionally stiff straw and high weight per bushel. It was also one of the earlier maturing varieties, averaging six days earlier than the two-rowed, rough-awned variety, Canadian Thorpe. However, the latter variety was superior in yielding capacity.

LITERATURE CITED

1. AAMODT, O S. and JOHNSTON, W. H. Newal, a promising new smooth-awned variety of barley for Alberta. University of Alberta, Circular. (In press)
2. ———— and JOHNSTON, W. H. Reaction of barley varieties to infection with covered smut, *Ustilago hordei* (Pers.) K. & S. Canadian Jour. Res. (In press.)
3. ———— and TORRIE, J. H. The relation between awns and yield in spring wheat. Can Jour Res. *11* . 207-212 1934.
4 CHRISTENSEN, J. J. and GRAHAM, T. W. Physiologic specialization and variation in *Helminthosporium gramineum* Rab. Minn. Agr. Exp. Sta. Tech. Bul 95. 1934.
5. DOWN, E. E., BROWN, H. M. and CLARK, F. H Barley for Michigan farms. Part II Barley varieties. Mich. Agr. Exp. Sta. Spec. Bul. 191. 1929.
6. HARLAN, H. V. Smooth-awned barleys. Jour. Amer Soc Agron. *12* : 205-208. 1920.
7. ———— and ANTHONY, S. Development of barley kernels in normal and clipped spikes and the limitations of awnless and hooded varieties. Jour. Agr. Res. *19* . 431-472 1920.
8. ———— and POPE, M. N. Ash content of the awn, rachis, palea and kernel of barley during growth and maturation. Jour. Agr. Res. *22* : 433-449. 1921.
9. HARRINGTON, J. B. Barley with barbless beards. The Western Producer, December 21 (p. 18). 1933.
10. HARRISON, T. J. Studies on the malting qualit, of barley. Sci. Agr. *14* · 131-135. 1933.
11. HAYES, H. K. Breeding improved varieties of smooth-awned barleys. Jour. Hered. *17* : 371-382. 1926.
12. ———— and WILCOX, A. N. The physiological value of smooth-awned barleys. Jour. Amer. Soc. Agron. *14* : 113-118. 1922.
13. ————, STAKMAN, E. C., GRIFFEE, F. and CHRISTENSEN, J. J. The reaction of barley varieties to *Helminthosporium sativum*. Minn. Agr. Exp. Sta. Tech. Bul. 21. 1923.

14. Johnston, W. H. Studies on the dehulling of barley kernels with sulphuric acid and on the inheritance of reaction to covered smut *Ustilago hordei* (Pers.) K. & S. infection in crosses between Glabron and Trebi barleys. Can. Jour. Res. *11* : 458-473. 1934.

15. ———— and Aamodt, O. S. The breeding of disease-resistant, smooth-awned varieties of barley. Can Jour. Res. (In press.)

16. Powers, L. and Hines, L. Inheritance of reaction to stem rust and barbing of awns in barley crosses. Jour. Agr. Res. *46* : 1121-1129. 1933.

17. Shands, R. G., Leith, B. D., Dickson, H. L. and Shands, H. L. Stripe resistance and yield of smooth-awned barley hybrids. Wis. Agr. Exp. Sta. Res. Bul. 116. 1933.

18. Stevenson, F. J., Bridgeford, R. O. and Crim, R. F. Barley in Minnesota. Minn. Agr. Exp. Sta. Spec. Bul. 135. 1930.

Résumé

Variétés d'orge à barbe lisse. O. S. Aamodt et W. H. Johnston, Université de l'Alberta, Edmonton, Alta.

Le comportement agronomique et la résistance aux maladies d'un certain nombre de variétés d'orge promettantes, à barbe lisse, cultivées à l'Université de l'Alberta, Edmonton, pendant les cinq années de 1930-34, sont l'objet de cette étude. En général les variétés d'orge à barbe lisse ont soutenu très avantageusement la comparaison avec les variétés à barbe rude O.A.C. No. 21 et Trebi. En tant que groupe, les espèces à barbe lisse avaient une paille beaucoup plus forte que les autres et leur étaient égales quant à la longueur de la paille et à la précocité de maturité. Au point de vue du rendement et du poids par boisseau, l'orge Newall est venue première parmi les variétés à barbe lisse et à six rangs qui étaient à l'essai; elle a dépassé également la O.A.C. No. 21 et la Trebi sous ces rapports. Les orges Comfort et Regal soutenaient très avantageusement la comparaison avec la O A.C. No. 21 en capacité de rendement et en poids par boisseau. Les Glabron et Velvet se sont montrées inférieures au point de vue du rendement aux autres espèces à barbe lisse et à six rangs, mais leur poids par boisseau était satisfaisant. A en juger par les données limitées qui ont été recueillies, la Wisconsin sans barbes No. 38 paraît être l'égale de la Comfort et de la Regal en capacité de rendement, mais cette variété est celle qui pesait le moins par boisseau de toutes les variétés à l'essai. L'orge Spartan à barbe lisse et à deux rangs, avait une paille exceptionnellement raide et un poids élevé par boisseau. C'était également l'une des plus précoces à mûrir; elle était en moyenne de six jours plus précoce que la Canadian Thorpe, une variété à barbe rude et à deux rangs, mais cette dernière lui était supérieure au point de vue du rendement.

STUDIES ON THE CONTROL OF ROOT-ROT DISEASES OF CEREALS CAUSED BY *FUSARIUM CULMORUM* (W.G. SM.) SACC. AND *HELMINTHOSPORIUM SATIVUM* P., K., AND B.

III. EFFECT OF SEED TREATMENT ON THE CONTROL OF ROOT ROT AND ON THE YIELD OF WHEAT[1]

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Treating cereal seed with fungicides to prevent certain seed-borne diseases has now become a well established agricultural practice, but comparatively little experimentation has been done to determine the effectiveness of seed treatment in preventing the development of soil-borne diseases of cereals, such as the common root rot caused by species of *Fusarium* and *Helminthosporium*. This disease is very common in Western Canada and causes annually considerable loss (*1*); and, as it tends to increase in severity in fields subjected to continued cropping with cereals, it is becoming one of the most destructive cereal diseases in the Prairie Provinces.

Greaney and Bailey (*3*) found that seed treatment with Semesan afforded protection to seedlings of wheat, oats, and barley against attacks by some common root-rotting fungi. Simmonds and Scott (*8*) reported that certain new organic mercury-compounds protected seedlings from attacks by *Fusarium culmorum* and *Helminthosporium sativum* in greenhouse tests. Leukel, Dickson, and Johnson (*6*) and O'Brien and Dennis (*7*), while themselves working with seed-borne diseases, gave an adequate resumé of other work with seed treatments in which soil-borne, root-rotting diseases of cereals were investigated.

The present paper gives the results of laboratory, greenhouse, and field studies, designed to determine the effect of various seed disinfectants on the control of the common root-rot disease of wheat caused by *Fusarium culmorum* (W.G. Sm.) Sacc. and *Helminthosporium sativum* P., K., and B.

LABORATORY AND GREENHOUSE EXPERIMENTS

The Relative Efficiency of Some Seed Disinfectants as Preventatives of "Seedling Blight" and Root Rot in Cereals

In this experiment the value of six different fungicides on four varieties of cereals was tested. The treatments included formaldehyde (one part of commercial Formalin to 320 parts of water), iodine-infusorial earth dust (containing 5% iodine by weight), nickel-sulphide dust, copper carbonate dust, Semesan and Ceresan. The fungicides, except formaldehyde, were applied to the seed as dusts. The rate of application for the dusts was 3 ounces (85 05 grams) per bushel (0.35239 hls.) of grain, except where wheat seed was treated with Ceresan, when the quantity of dust was reduced to 2 ounces (56 7 grams) per bushel. The seed treated with formaldehyde was steeped in the solution for one-half hour, then drained, and covered for 2 hours before sowing.

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The varieties of cereals included in the test were Marquis and Mindum wheats, Canadian Thorpe barley, and Banner oats. Treated and untreated seed lots of each variety were planted in sterile soil artificially infected with *F. culmorum*, and in sterile soil alone. The methods of soil sterilization, infestation, and planting of the seed have been described in a previous paper (*5*). Uniform conditions of moisture in the soil were maintained during the experiment. The plants were grown in a greenhouse of which the atmospheric temperature was maintained within the range 18–22° C. Two weeks from the date of seeding counts were made of the healthy and diseased seedlings. Table 1 summarizes the data of four trials.

TABLE 1.—EFFECT OF TREATING SEED WITH VARIOUS FUNGICIDES ON THE DEVELOPMENT OF SEEDLING ROOT ROT OF CEREALS CAUSED BY *Fusarium culmorum*. (AVERAGE OF FOUR TRIALS WITH FOUR VARIETIES OF CEREALS)

Fungicides	Soil Treatments			
	Control		Infested with *F. culmorum*	
	Plants emerged	Emerged plants diseased	Plants emerged	Emerged plants diseased
	%	%	%	%
Formalin Steep	81	38	14	100
Iodine-Infusorial earth	88	18	47	39
NiS dust	95	8	70	49
$CuCO_3$ dust	96	16	71	45
Ceresan	90	2	89	4
Semesan	97	2	96	8
Control	91	36	70	41

It will be seen from Table 1 that some of the seedlings grown in supposedly sterile soil showed root rot. This was caused by chance contamination of the soil after the seed was sown. In no case, however, was any perceptible harm done to these seedlings; whereas, many of the seedlings grown in artificially infested soil failed to emerge, and of those that did emerge, many died or wilted badly before the notes were taken. The results show that under the conditions of the experiment the organic mercurials, Ceresan and Semesan, were considerably more effective in controlling root rot in seedlings than the other fungicides used. Copper carbonate was relatively ineffective, while formaldehyde actually increased the severity of the disease.

As copper carbonate is widely used as a seed treatment to control bunt of wheat, some information was desired as to why it gave inadequate control of root rot. Laboratory experiments were therefore made to determine the relative value of copper carbonate as compared to Ceresan and Semesan as a preventative of spore germination and mycelial growth in the fungi *H. sativum* and *F. culmorum*.

In order that conditions for spore germination should be somewhat similar to those found in nature, the spores were germinated in soil extract to which the fungicides were added. The soil extract was prepared by

mixing one part of black-loam soil with two parts of distilled water, allowing the mixture to stand for six hours, and then decanting the supernatant fluid. This liquid was filtered and sterilized by autoclaving, and then allowed to cool. A calculated quantity of copper carbonate was added to a portion of the extract, and dilutions of the mixture were made by adding more extract according to need. Mixtures of each of the other two fungicides and the extract were similarly prepared, and dilutions were then made.

After the series of dilutions had been completed, drops of each dilution were placed on clean glass slides and inoculated with spores from a fresh culture of the fungus to be tested. The slides were then placed in moist chambers and incubated for 24 hours at room temperature. The average results of four tests with two fungi and six dilutions of each of the three fungicides are summarized in Table 2.

TABLE 2.—TOXICITY OF VARIOUS CONCENTRATIONS OF CERESAN, SEMESAN, AND COPPER CARBONATE TO SPORES OF *Fusarium culmorum* AND *Helminthosporium sativum*. (AVERAGE OF FOUR TRIALS.)

Dilution of fungicides	Spore germination classes*					
	H. sativum			*F. culmorum*		
	Ceresan	Semesan	$CuCO_3$	Ceresan	Semesan	$CuCO_3$
Control	5	5	5	5	5	5
1–100,000	4	3	3	3	2	3
1–80,000	4	3	2	2	2	3
1–60,000	4	3	2	2	1	3
1–40,000	2	2	1	1	1	3
1–20,000	0	0	1	0	0	2
1–10,000	0	0	1	0	0	2

*Class value	Range of germination percentages	Class value	Range of germination percentages
0	0	3	41–60
1	1–20	4	61–80
2	21–40	5	81–100

It is seen in Table 2 that Semesan and Ceresan completely prevented spore germination at 1–20,000 dilution while copper carbonate did not. The greater toxicity of the organic mercurials was further demonstrated through the fact that germtubes formed in solutions of these fungicides were generally very short, while those formed in the presence of copper carbonate grew almost as long as those in the controls.

The effect of the three fungicides on the mycelial growth of *H. sativum* and *F. culmorum* was also determined. Various soil extract and fungicide mixtures were prepared as in the spore-germination tests. To each dilution was added Difco potato-dextrose agar at the rate of 40 grams per litre. This provided a solid medium containing soil extract, the desired dilution of a fungicide, and sufficient nutrients to allow good growth of mycelium. After sterilization the medium was poured in 15 c.c. lots into sterile Petri dishes. When cool each plate was inoculated with actively-growing mycelium of *H. sativum* or of *F. culmorum*. After inoculation, the dishes were placed in an incubator maintained at room temperature. Ten days

later the diameters of the individual cultures were measured. The average diameter of four cultures of each fungus on each of the different dilutions of fungicides are given in Table 3.

TABLE 3.—THE EFFECT OF DIFFERENT CONCENTRATIONS OF CERESANS SEMESAN, AND COPPER CARBONATE ON THE MYCELIAL GROWTH OF *Helminthosporium sativum* AND *Fusarium culmorum*. (AVERAGE DIAMETERS OF 4 TEN-DAY-OLD CULTURES.)

Dilution of fungicides	Diameter of culture in millimeters					
	H. sativum			*F. culmorum*		
	Ceresan	Semesan	$CuCO_3$	Ceresan	Semesan	$CuCO_3$
Control	50 5	50 0	50 6	150 1	156 0	150 3
1–100,000	50 0	50 0	50 9	140 2	133 0	150 3
1– 80,000	30 1	25 0	50 0	70 6	76 1	150 0
1– 60,000	10 3	15 3	50 8	30 0	35 0	145 9
1– 40,000	0 0	7 5	50 1	10 1	27 2	140 3
1– 20,000	0 0	5 4	50 6	2 0	7 5	140 3
1– 10,000	0 0	2 1	50 0	0 0	2 5	140 0

It is seen from Table 3 that both Semesan and Ceresan reduced or prevented mycelial growth of *H. sativum* and *F. culmorum* at dilutions where copper carbonate had little effect. Ceresan evidently was the more toxic of the two mercurials. These results, as well as those summarized in Table 2, indicate, to some extent at least, why Semesan and Ceresan were able to control common root rot in greenhouse experiments while copper carbonate did not. The mercury compounds are more toxic than copper carbonate to spores and mycelium of these two fungi, a fact which appears to account for the control of the disease after seed treatment with Ceresan and Semesan.

The Relative Efficiency of Some Fungicidal Steeps in the Control of "Seedling Blight" and Root Rot of Wheat

The object of these experiments was (a) to determine whether certain fungicides which are commonly applied to seed as dusts would also be useful as fungicides when used in liquid form, and (b) to determine the dilutions and periods of seed-immersion which could be used without injury to the seed.

In the first test the comparative efficiency of Ceresan and Semesan when applied as dusts or steeps to seed grain was investigated. The dusts were applied to the seed according to the directions of the manufacturers. The steeps were prepared by mixing each fungicide with water and diluting according to need. The steep was applied by dipping the seed for one of three different time intervals. In all cases the seed was planted within one hour after treatment, in sterile soil or soil artificially infested with *F. culmorum*. The pots of soil were then placed in a greenhouse maintained at a temperature range of 20–22° C. After two weeks notes on seedling emergence, seedling blight and root rot data were taken; these are summarized in Table 4.

TABLE 4.—THE EFFECT OF DUST AND STEEP TREATMENTS PREPARED FROM TWO FUNGICIDES ON THE DEVELOPMENT OF SEEDLING ROOT ROT OF MARQUIS WHEAT CAUSED BY *Fusarium culmorum*. (AVERAGE OF 2 TRIALS.)

Treatment	Concentration of solution	Period of steep	Soil treatments: Control		Soil treatments: Infested with *F. culmorum*	
			Plants emerged	Emerged plants diseased	Plants emerged	Emerged plants diseased
	%	Minutes	%	%	%	%
Ceresan (Liquid)	5	1	93	1	·90	5
" "	5	2	89	0	90	2
" "	5	5	70	0	68	0
" "	25	1	16	0	18	0
" "	25	2	4	0	5	0
" "	25	5	0	0	2	0
Ceresan (Dust)	—	—	100	0	97	3
Semesan (Liquid)	5	1	100	0	98	2
" "	5	2	97	0	97	2
" "	5	5	98	0	96	1
" "	25	1	81	0	90	2
" "	25	2	62	0	75	4
" "	25	5	45	0	55	1
Semesan (Dust)	-	---	99	1 5	99	6
Control	—	- -	95	6	48	58

Table 4 shows that the dust treatments and the steep treatments (5% concentration of the fungicides and 2 minutes immersion of the seed) are almost equally effective in the control of root rot. Higher concentrations of the fungicides or longer periods of immersion may result in injury to the seed.

In a second test, made to study further the utility of steeps in root-rot control, four different fungicides were used. These fungicides, namely, Uspulun, Semesan, Ceresan, and New Improved Ceresan, were mixed separately with water to form steeps of 25%, 12.5%, 5 0% and 2 5% concentrations. Marquis wheat seed was immersed in the steep for 2 minutes, and then planted in sterile soil and in soil infested with *F. culmorum*. The plants were grown in a greenhouse maintained at a temperature of 20-22° C. After 14 days notes on the development of disease in the plants were taken. The results obtained from two separate trials are given in Table 5.

It is seen from Table 5 that good protection to the seedling from invasion by the root-rotting fungus, *F. culmorum*, was given by the lowest fungicide concentration used. At this concentration Semesan and New Improved Ceresan were the most effective, but as New Improved Ceresan caused some seed injury and Semesan did not, Semesan was considered the more desirable of the two. In all cases, however, good protection from root rot was afforded the seedlings by the steep, as indicated by the great difference in disease development found in treated and untreated plants grown in the infested soil.

TABLE 5.—EFFECT OF TREATING SEED WITH DIFFERENT CONCENTRATIONS OF FOUR FUNGICIDES ON THE DEVELOPMENT OF SEEDLING ROOT ROT OF WHEAT CAUSED BY *Fusarium culmorum*. (AVERAGE OF 2 TRIALS.)

Fungicides	Concentration of solution	Soil treatments			
		Control		Infested with *F. culmorum*	
		Plants emerged	Emerged plants diseased	Plants emerged	Emerged plants diseased
	%	%	%	%	%
Uspulun	25.0	82	0.0	89	7.8
"	12.5	89	1.1	85	3.5
"	5.0	95	2.1	91	7.7
"	2.5	100	0.0	85	16.4
Control	0.0	93	3.0	0	--
N. I. Ceresan	25.0	1	0.0	0	—
"	12.5	1	0.0	1	0.0
"	5.0	6	0.0	14	0.0
"	2.5	60	0.0	54	5.5
Control	0.0	95	3.2	3	100.0
Semesan	25.0	77	0.0	86	4.7
"	12.5	94	0.0	96	6.2
"	5.0	95	1.1	95	4.2
"	2.5	98	1.0	93	5.3
Control	0.0	97	2.1	0	—
Ceresan	25.0	2	0.0	6	0.0
"	12.5	30	0.0	39	2.5
"	5.0	85	0.0	84	4.7
"	2.5	98	0.0	84	13.1
Control	0.0	94	2.1	0	--

Effect of Seed Treatment on Seed and Seedling

It was observed throughout the preceding experiments that the exterior of the seed which had been treated with the organic mercury-compounds presented a fresh, bright appearance, even after the seed had remained two weeks in heavily infested soil and had produced a seedling several inches in height. The seed, however, by this time had lost considerable volume and sections of the remnant showed that only a small fraction of the original seed contents remained. All the endosperm had evidently been used as food for the growing plant. On the other hand, when the seed had been treated with copper carbonate, nickel sulphide, iodine-infusorial earth dust, or formaldehyde steep, it showed only partial preservation. Untreated seed, after remaining 14 days in infested soil, was as plump as before sowing, but was considerably discoloured and the contents had assumed a gelatinous nature. In the latter case the seed contents had been largely replaced by fungal hyphae which found ready access to the unprotected seed and an ample supply of nutrients in it for their use.

In the experiments dealing with different fungicides and methods of application it was seen, furthermore, that seedlings arising from seed which had received poor protection by seed treatment from fungal invasion

always developed more slowly than did seedlings from well-protected seed. These unprotected seedlings almost invariably became infected shortly after the seed had germinated, and wilted in most instances. The protected seedlings grew well and were relatively free from disease when they were pulled for examination.

When Ceresan or New Improved Ceresan was applied to the seed as a steep in concentrations higher than 5%, or when the length of the steep was greater than 2 minutes, the seed became damaged. Although such seed germinated, the coleoptile grew very slowly and became broad and bulbous in appearance. The extent of the deformity varied with the strength of the solutions, being very pronounced when the concentration was high.

Seed treated with formaldehyde and planted in infested soil remained relatively free itself from invasion by *F. culmorum*. The treatment appeared however, to have an adverse effect on the growth of the seedlings, thus predisposing them to the disease.

FIELD EXPERIMENTS

Extensive trials have been made by the writers during the three years 1932 to 1934 to determine the value of seed disinfection in the control of root rot of wheat caused by species of *Fusarium* and *Helminthosporium* under field conditions. The trials consisted of rod-row experiments and large-plot tests. To provide an adequate test of the relative fungicidal effectiveness of several competing seed disinfectants, the experiments were so arranged that the heterogeneity of the soil as well as the differences between the seed treatments could be accurately evaluated. Randomized Block and Latin Square plans of plot arrangement were used. The "analysis of variance" method, devised and described by Fisher (*2*), was used for analysing the data.

Rod-row Experiments

Dust and liquid preparations of Semesan, Ceresan, New Improved Ceresan, and copper carbonate were tested in 1932 and 1933. Dressings of Semesan and copper carbonate were applied at the rate of 3 ozs., Ceresan at 2 ozs., and New Improved Ceresan at ½ oz. per bushel of grain. For the liquid treatments, 0 5% water solutions of Ceresan, Semesan, New Improved Ceresan, and copper carbonate were prepared. The seed was placed in cheese-cloth bags and immersed for 2 minutes. The seed was then spread out on a clean cloth to dry. In 1934 the dust treatments used were as in the 1933 experiment, but the only liquid treatment tested was formaldehyde. For this wet treatment the seed was soaked for one-half hour in a solution of commercial Formalin (1 : 320), then drained, and afterwards kept covered for 2 hours. In all tests dry untreated seed, and seed soaked in water for 2 minutes were used as controls.

The general arrangement of the rod row experiments was as follows. The seed was planted in rod rows placed one foot apart, in adequately replicated blocks. Each block was divided into plots representing different seed treatments and the control. In order to insure a positive attack by root-rot fungi, one-half of each plot (a split-plot) was artificially infested with *F. culmorum*, while the other split-plot was not artificially infested

and thus served as a soil control. The disposition of the seed treatments and the soil treatments (artificially-infested and ordinary field soil) was purely at random within each block. Each split-plot consisted of two rod rows, in one of which the seed was spaced in the row (100 seeds per row) and in the other a weighed quantity of seed was distributed evenly. The field technique and methods of recording the amount of disease as described by Greaney and Machacek (4) were utilized in the present experiments. Plant-emergence, disease-rating, and yield data were treated by the "Analysis of Variance" and "Z" test (Fisher (2)).

Mindum and Marquis were the wheat varieties used in 1932. In 1933 and 1934 Mindum only was used. The seed was hand-selected but not scarified. The fungus selected for infesting the field plots was *Fusarium culmorum* (W.G. Sm.) Sacc. and the culture used was very pathogenic on wheat. The plots were artificially infested by applying at seed level in each rod row 600 c.c. of soil inoculum of *F. culmorum*.

TABLE 6.— COEFFICIENTS OF CORRELATION BETWEEN ROOT-ROT DISEASE RATING AND YIELD OF WHEAT

Year	Variety	Correlation coefficient	t*
1932	Mindum	−0 2916	2.69
1932	Marquis	−0 3541	3 34
1933	Mindum	−0 5420	7.66
1934	Mindum	−0 0744	0 72

*1% point = 2 57.

In order to ascertain what significance may be attached to the disease rating as a true measure of the amount of injury caused by cereal root-rot fungi on wheat, disease ratings and yields of individual plots were correlated in these experiments. The significance of the coefficients of correlation was determined according to the method described by Fisher (2). The results of these analyses are presented in Table 6.

The t values for 1932 and 1933 exceed the 1% points and thus establish the significance of the coefficients. These results show that increases in the degree of infection caused by root-rot fungi result in decreases in the yield of wheat, and confirm the findings of Greaney and Machacek (4) that the disease rating constitutes a reliable measure of the amount of root-rot disease on wheat under field conditions. Thus, in examining the results obtained in 1932 and 1933, the disease rating was considered an accurate measure of the root-rot control secured through seed treatment. In 1934, owing probably to the exceedingly dry conditions which prevailed during the early part of the season, the disease rating was not significantly associated with yield.

Table 7 gives the complete analysis of variance for plant emergence, disease rating, and yield of the 1933 experiment, and illustrates the method of analysis utilized in all rod-row experiments reported in this paper.

The significance of the results of the experiment is assessed by the Z test, in which the variance due to any known cause is compared to the variance due to error. The Z values obtained for dust and liquid seed treatments in 1933 are not significant. Thus, as illustrated in Table 7, the values of Z for plant emergence, disease rating, and yield, for liquid and dust seed treatments are less than the values required for significance at the 5% levels. It may be concluded, therefore, that the differences

TABLE 7.—COMPLETE ANALYSIS OF VARIANCE FOR PLANT EMERGENCE, DISEASE RATING AND YIELD (SEED TREATMENT EXPERIMENT, 1933)

	Degrees of freedom	Sum of squares	Mean square	Z	5% point
Plant Emergence					
Controlled error	8	2174 65	271 83		
Seed treatments	3	1770 03	590 01	0 9990	0 5117
Soil treatments	2	6084 18	3042 09	1 8191	0 5777
Seed treatments × soil treatments	6	2837 27	472 88		
Error (1)	52	4177 85	80 34		
Dusts and liquids	1	72 25	72 25	0 3113	0 6933
Dusts and liquids × seed treatments	3	469 47	156 49		
Dusts and liquids × soil treatments	2	14 29	7.14		
Interaction (second order)	6	40 16	6 69		
Error (2)	60	2325 83	38 75		
Total	143	19965 98			
Disease Rating					
Controlled error	8	1512 81	189 10		
Seed treatments	3	422 26	140 75	0 6536	0 5117
Soil treatments	2	3774 06	1887 03	1 9516	0 5777
Seed treatments × soil treatments	6	1420 20	236 70		
Error (1)	52	2026 07	38 96		
Dusts and liquids	1	56 78	56 78	0 3381	0 6933
Dusts and liquids × seed treatments	3	263 07	87 69		
Dusts and liquids × soil treatments	2	7 09	3 54		
Interaction (second order)	6	38 35	6 39		
Error (2)	60	1549 87	25 83		
Total	143	11070 56			
Yield (Bushels per acre)					
Controlled error	8	3232 29	404 04		
Seed treatments	3	52 60	17 53	—	- -
Soil treatments	2	422 39	211 19	1 1116	0 5777
Seed treatments × soil treatments	6	413 36	68 90		
Error (1)	52	1189 07	22 86		
Dusts and liquids	1	1 73	1 73	—	—
Dusts and liquids × seed treatments	3	164 53	54 84		
Dusts and liquids × soil treatments	2	14 33	7 16		
Interaction (second order)	6	34 39	5 73		
Error (2)	60	632 03	10 53		
Total	143	6156 82			

observed between liquid and dust treatments are not significant ones. The analysis therefore establish the fact that, as far as seed treatments for root-rot control are concerned, the dusts were just as effective as the

liquids. Consequently, in presenting the results of individual fungicides used in these field experiments, the average results of dust and liquid treatments are given.

The values of Z for soil treatments (soil artificially infested and ordinary field soil) in Table 7 greatly exceed the 5% points, and indicate that a high degree of significance can be attached to the differences in soil treatments in this experiment From the results it may be assumed that the differences observed in plant emergence, disease rating, and yield were due to positive attacks of cereal root-rot fungi. The importance of establishing significant differences between soil treatments in experiments with root-rot diseases of cereals has already been discussed (*4*).

Examination of Table 7 shows that the Z values for seed treatments, plant emergence, and disease rating are highly significant. In order, however, to establish beyond question the practical value of any given disinfectant, it is necessary to obtain significant differences between yields derived from the various treatments under field conditions.

The analysis of the complete results obtained from rod-row seed treatment experiments of 1932 and 1934 established significant differences in plant emergence and disease rating, and the analysis of the 1934 data indicated, in addition, differences in yields beyond the limit set for significance. When the significance of seed and soil treatment differences had been established, a detailed examination of the results was made. The standard error of the means of treatments and the complete results of the three years' experiments are summarized in Table 8.

TABLE 8 -EFFECT OF TREATING SEED WITH CERESAN, SEMESAN, NEW IMPROVED CERESAN, COPPER CARBONATE AND FORMALIN ON PLANT EMERGENCE, ROOT-ROT DISEASE RATING AND YIELD OF MINDUM WHEAT. RESULTS OF ROD-ROW TESTS AT WINNIPEG, MAN, IN 1932, 1933 AND 1934.

Year		Ceresan	Semesan	New Imp Ceresan	Copper carbonate	Formaldehyde	No treatment	Standard error*
1932	Plant emergence (%)	55 4	54 8	56 2	50 9	—	47 2	1 41
	Disease rating	66 2	65 7	64 7	68 8	—	71 1	0 89
	Yield (Bu per ac)	23 7	24 9	24 0	23 2	—	22 9	—
1933	Plant emergence (%)	64 2	—	63 1	57 8	—	55 9	1 49
	Disease rating	65 3	—	66 2	68 1	—	69 7	1 04
	Yield (Bu per ac)	18 5	—	17 3	18 2	—	17 0	—
1934	Plant emergence (%)	81 0	81 5	83 3	76 9	59 7	77 7	1 37
	Disease rating	46 1	46 2	44 0	49 8	59 1	48 0	1 12
	Yield (Bu per ac)	30 1	32 1	32 9	33 7	21 3	30 5	1 95

*Differences between means required for significance = Standard error $\times 2\sqrt{2}$

The results in Table 8 show that although significant differences in plant emergence and disease rating occur, thus indicating the effectiveness of individual seed treatments, these are not always accompanied by significant yield differences.

In each year, seed treated with Ceresan, Semesan or New Improved Ceresan germinated better than untreated seed, and the amount of root

rot was reduced by seed disinfection to a significant degree. Copper carbonate did not influence seed germination, and it was inferior to the organic mercurials in reducing the incidence of root rot. In 1934 seed treatment with formaldehyde reduced emergence to such a degree that yield was significantly below that of the control, while the disease rating was considerably higher.

In general the results obtained during the three years, on soil infested with *H. sativum* and *F. culmorum*, confirm the findings of Simmonds and Scott (*9*), Bailey and Greaney (*3*), and others, and show that wheat seed disinfected with certain organic mercury-compounds germinates better than seed left untreated, or treated with copper carbonate or formaldehyde. The yield of wheat, however, was not constantly and significantly influenced by seed treatment.

Large-plot Tests

The large-plot tests were made at Winnipeg in 1932 and 1933, and at Winnipeg and Brunkild, Man., in 1934. The fields chosen for the tests consisted of fall-ploughed clay-loam soil which had been cropped the preceding year with wheat. These fields were naturally infested with the common cereal root-rotting fungi, the Brunkild field being selected particularly on account of the prevalence of *Helminthosporium sativum* in the soil.

Dust and liquid seed treatments consisting of Ceresan, Semesan, New Improved Ceresan, and copper carbonate were tested in 1932 and 1933 on Marquis and Mindum wheat. In 1934 Mindum only was used. The seed was treated in large lots a short time before seeding. The methods and rates of fungicide applications were similar to those used in the rod-row experiments.

The Latin Square method of plot arrangement was used. The seed was sown in 1/200th acre plots by means of an ordinary grain drill. Alleys, 3 feet in width, separated the plots. At harvest time, the border rows were removed, and the grain of each plot was harvested and threshed separately to obtain yield data. The methods of seed treatment and soil management were very similar to those employed in ordinary agricultural practice.

The intensity of root rot in individual plots was not recorded in 1932 and 1933. The plots, however, were watched closely during the growing season, and the general development of disease was observed from time to time. In 1934, however, a disease rating expressing the amount of root rot was determined for each plot.

The large-plot tests were designed to determine the effect of seed treatment on yield of wheat. Examination of the yield results of the different experiments indicated that a real effect due to different seed treatments was being studied. In order to determine whether the yields were of significant value a thorough analysis of the data was made. Fisher's analysis of variance method was adopted for this purpose. This method permits an evaluation of the experiment as a whole, as well as of the individual treatments. Table 9 gives the analysis of variance for yield of two Latin Square experiments made at Winnipeg in 1932.

TABLE 9.—ANALYSIS OF VARIANCE FOR YIELD OF MINDUM AND MARQUIS WHEAT. LATIN SQUARE SEED-TREATMENT EXPERIMENTS, 1932

Marquis

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5% point
Rows	7	1760 60	251 51		
Columns	7	741 80	105 90		
Liquids and dusts	1	42 09	42 09	0 0244	0 6923
Seed treatments	3	415 44	138 49	1.5070	0 4017
Liquids and dusts × seed treatments	3	69 93	23 31		
Error	42	735 37	17 50		
Total	63	3765 23			

Mindum

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5% point
Rows	7	1880 86	268 69		
Columns	7	795 41	113 63		
Liquids and dusts	1	10.48	10 48	—	—
Seed treatments	3	295 63	98 54	0 6826	0 4017
Liquids and dusts × seed treatments	3	204 48	68 16		
Error	42	1057 13	25 16		
Total	63	4243 99			

The analysis in Table 9 establishes the significance of seed treatment differences, but no significant difference is shown between the dust and liquid fungicide application. The 1932 results with Marquis and Mindum wheat were confirmed in 1933. The evidence supports the conclusions drawn from the rod-row tests, and shows that the dust and the liquid fungicides were equally satisfactory as a means of controlling root rot in wheat. Because a dry treatment involves less time and labour than a wet treatment, the use of dust fungicides is preferable when large quantities of grain are treated.

The analysis of the complete data obtained from the 1932, 1933, and 1934 large-plot tests indicated the existence of significant differences in yield due to seed treatment. A detailed examination of individual treatments in each experiment was made. A summary of the three-years' results is presented in Table 10.

Table 10 shows that in 1932 Marquis wheat seed treated with the organic mercury compounds produced a crop which outyielded to a significant degree the crop from untreated seed. In that year an increase of 8 bushels per acre was obtained by disinfecting seed with Ceresan. None of the treatments gave significant yield differences in 1933. In 1934 the results at Winnipeg and Brunkild were negative. In that year the untreated seed of Mindum wheat yielded a better crop than did seed treated with Ceresan or copper carbonate.

From the results of the three-years' experiments it would seem that the effect of seed disinfection on yield varies in an unaccountable manner. The unusually dry conditions which prevailed in Manitoba during the early part of the growing seasons may be closely associated with the poor

TABLE 10.—EFFECT OF SEED TREATMENT ON THE YIELD OF WHEAT IN 1932, 1933 AND 1934. (AVERAGE RESULTS OF 1/200TH ACRE PLOTS IN A LATIN SQUARE).

Year	Variety	Ceresan	Semesan	New Imp. Ceresan	Copper carbonate	No. treatment	Standard error*
1932	Marquis	24.6	21.0	21.3	—	16.4	1.48
	Mindum	20.7	15.9	21.4	-	18.4	1.77
1933	Marquis	11.7	–	9.5	9.7	10.0	0.80
	Mindum	10.2	-	10.3	9.4	9.7	0.58
1934	Mindum (B)†	9.6	8.6	9.3	8.9	10.9	0.59
	Mindum (W)	14.5	12.9	13.1	11.9	14.7	0.52

*Difference between means required for significance = Standard error $\times 2\sqrt{2}$
†(B) - Brunkild field. (W)- Winnipeg field

yield results obtained in 1933 and 1934. These results suggest that the efficiency of seed treatment in the control of root-rot diseases of wheat depends, to some degree at least, on the amount of moisture in the soil at the time of, and subsequent to seeding. In general, however, the field experiments indicate the value of seed disinfection with organic mercury preparations for the control of root-rot of wheat caused by *H. sativum* and *F. culmorum*, although further studies are necessary to determine under what conditions these treatments are most beneficial.

SUMMARY

In greenhouse experiments, seed treatment with Semesan and Ceresan, both in liquid and dust form, and with New Improved Ceresan and Uspulun in liquid form, prevented root rot and wilt caused by *Fusarium culmorum* in seedling plants of wheat, oats, and barley. In liquid form these fungicides were found to give the best results at a concentration of 5% and a time interval of 2 minutes for the steep. Semesan gave slightly better control of the disease than Ceresan and New Improved Ceresan, and, unlike them, caused little or no seed injury. Uspulun was the least effective of the four fungicides.

Copper carbonate as a steep and a dust, and nickel sulphide and iodine-infusorial earth as dusts, gave practically no control. Cultural studies indicated that copper carbonate was but slightly toxic to *F. culmorum* and *Helminthosporium sativum*.

Formaldehyde as a steep increased the intensity of the disease. The treatment appeared to have an adverse influence on the growth of the seedlings, and probably on that account rendered them more susceptible to fungal attack.

Field experiments made in 1932, 1933, and 1934 showed that the organic mercury-fungicides gave good control of root-rot caused by species of *Helminthosporium* and *Fusarium*, as indicated by the increased seedling emergence and the decreased disease rating in mature plants. Copper carbonate did not control the disease. Formaldehyde tested only in 1934, tended to increase the amount of disease, and markedly decreased the yield. As far as effectiveness in controlling the disease was concerned, the dust or the liquid treatments with any one of these compounds are of about equal value.

In 1932 all the organic mercury-compounds significantly increased the yield of Marquis wheat. Where Ceresan was used the yield was increased 8 bushels per acre. In 1933 and 1934 yields were not significantly increased.

LITERATURE CITED

1. DOMINION LABORATORIES OF PLANT PATHOLOGY (WESTERN). Studies in Cereal Diseases. IX. Losses caused by diseases of cereals in Western Canada. Dom of Can. Dept. of Agr. Pamphlet 152. N.S. 1933.
2. FISHER, R. A. Statistical methods for research workers. Fourth Edition, Oliver and Boyd, London and Edinburgh. 1928.
3. GREANEY, F. J. and D. L BAILEY. Studies in Cereal Diseases II. Root-rots and foot-rots of wheat in Manitoba. Dom. of Can, Dept. of Agr. Bul. 85. N.S. 1927.
4. ——————, and J. E. MACHACEK. Studies on the control of root-rot diseases of cereals caused by *Fusarium culmorum* (W.G Sm.) Sacc. and *Helminthosporium sativum* P., K., and B. I. Field methods with root-rot diseases. Sci. Agr. *15* : 228-240 1934
5. —————— - - ————- - Studies on the control of root-rot diseases of cereals caused by *Fusarium culmorum* (W G Sm) Sacc and *Helminthosporium sativum* P , K., and B II Pathogenicity of *Helminthosporium sativum* as influenced by *Cephalothecium roseum* Corda Sci. Agr. *15* . 377-386. 1935.
6. LEUKEL, R. W., J. G. DICKSON and A G JOHNSON. Experiments with dusts for controlling stripe disease of barley Phytopath. *17* · 175-180. 1927.
7. O'BRIEN, D. G , and R. W. G DENNIS *Helminthosporium* disease of oats. West of Scotland Agr Coll Res Bul. No 3 1933.
8. SIMMONDS, P. M., and G. A SCOTT. Seed treatment for the control of seedling blight in cereals. Sci. Agr. *8* . 502-511. 1928

Résumé

Etude du traitement de la pourriture des racines des céréales causée par Fusarium Culmorum (W. G. Sm.) Sacc. et Helminthosporium Sativum P., K., et B. J. E. Machacek et F. J. Greaney, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

Dans les expériences conduites en serre, le traitement de la semence au moyen de Semesan et de Ceresan, sous forme liquide ou en poussière, et avec le nouveau Ceresan amélioré et l'Upsulun sous forme liquide, a empêché la pourriture de la racine et la brûlure causée par *Fusarium culmorum* dans les plantules de blé, d'avoine et d'orge. Sous forme liquide ces fongicides ont été les plus satisfaisants en concentration de 5 pour cent et à intervalle de 2 minutes pour la macération. Le Semesan a paru avoir un peu plus d'effet que le Ceresan et le nouveau Ceresan amélioré, et il s'est montré supérieur à ces derniers en ce sens qu'il n'abîmait point la semence. L'Upsulun est celui des quatre fongicides qui a été le moins efficace. Le carbonate de cuivre employé en bain et en poussière, le sulfure de nickel et la terre infusoriale-iodée employée en poussière, n'ont eu presque pas d'effet. Les essais de culture ont indiqué que le carbonate de cuivre n'est que légèrement toxique pour *F. culmorum* et *Helminthosporium sativum*. La formaldéhyde employée en bain a augmenté l'intensité de la maladie. Le traitement parait avoir exercé un effet retardataire sur la végétation des plantules, et les a probablement, à cause de cela, rendues plus sensibles à l'attaque des champignons. Les expériences conduites dans le champ en 1932, 1933 et 1934 ont montré que les fongicides organiques de mercure ont donné un bon contrôle de la pourriture de la racine causée par les espèces *Helminthosporium* et *Fusarium*, indiqué par le nombre plus élevé de plantules et par la diminution de la fréquence de la maladie chez les plantes adultes. Le carbonate de cuivre n'a pas enrayé la maladie. La formaldéhyde qui n'a été essayée qu'en 1934 avait une tendance à augmenter la quantité de maladie et elle a fortement abaissé le rendement. En ce qui concerne l'efficacité au point de vue de l'enrayement de la maladie, la poussière ou le traitement liquide avec l'un ou l'autre de ces composés ont à peu près une valeur égale. En 1932 tous les composés organiques de mercure ont accru dans des proportions notables le rendement du blé Marquis. Lorsque le Ceresan était employé, le rendement s'est accru de 8 boisseaux à l'acre. L'augmentation de rendement a été peu sensible en 1933 et 1934.

UNDERDRAINAGE EXTENSION WORK IN ONTARIO[1]

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In 1905 Professor J. B. Reynolds was head of what was then known as the Department of Physics and English at the Ontario Agricultural College. Realizing the necessity of some assistance that would enable farmers to meet their drainage problems, he made a recommendation early that year to the Minister of Agriculture. He proposed that the Department take levels and prepare plans giving all specifications for drainage installation, the farmer being responsible for necessary travelling expenses. This was kindly received by the Minister of Agriculture. At the Canadian National Exhibition Professor Reynolds was asked to address the farmers on the subject of "Farm Drainage", when he announced for the first time to the farmers the assistance his department was prepared to give in this direction. Following this announcement, correspondence was received from seven different centres in Ontario, namely, Grimsby, Exeter, Wiarton, Mt. Forest, Whitby, Fergus and Lancaster.

In 1906 the aforementioned department was divided, Professor Reynolds taking charge of the English Department and Professor Day, who had been assistant to Professor Reynolds for several years, the Physics Department. During that season, however, Professor Reynolds fulfilled his obligations with regard to correspondence he had received in connection with drainage surveys and made twelve personal surveys. During the same summer Professor Day made fourteen surveys.

During the early part of 1907 a number of articles were written for the Farmers Advocate, and announcements with regard to drainage surveys made in a number of the weekly publications, with the result that during the spring 126 applications were received. Of these 70 were attended to, 34 being done by Mr. Thon, Professor Day's assistant, 25 by Professor Day and 11 by Mr. Wolverton, whose services were obtained for one month.

During 1908 three extra men were employed in connection with drainage work; 166 applications were received and 100 surveys made. During this year the department became interested in the operation of the first ditching machine known to be in the country, owned and operated by Mr Jacob Schihl of Woodslee, Essex county Following this demonstration, Professor Day made a trip to the Buckeye factory, Findlay, Ohio, and was quite impressed with the possibilities of the machine they were making. In 1909, 302 applications were received for this work. During the same year two other ditching machines were imported.

Interest has continued in drainage work throughout the intervening years. Up until the spring of 1918 the survey work was carried on by students during the summer time. It was found that this method had some objections, namely, the yearly necessity of breaking in new men and very often having them for one year only, releasing them when they were really getting into shape to handle the difficult problems that turned up

[1] Paper read before the Agricultural Engineering Group of the C S T A. at Macdonald College, P Q, June 26 and 27, 1934

[2] Department of Agricultural Engnieering.

on some of the jobs. Secondly, the lack of help during October and November when drainage work is usually very active and the students had returned to their classes. It was decided in 1918 to make permanent appointments in strategic points within the province so the efficiency of the work could be raised. This method is still being used and is proving satisfactory. At times it has been necessary to appoint a couple of extra men during the summer time to help with the rush work.

Up until the time of the permanent appointments in 1918 the old method of operation has been in vogue, that is, the men received a certain salary and collected their expenses from the parties for whom they worked. With the permanent appointments the men received salaries and also expenses and for three years no charge was made for the work to the farmers. This arrangement was unsatisfactory because of the fact that it did not put any value on the work and a number of the farmers requested surveys of their farms in order to get maps without having in mind the installation of any drains whatsoever. It was decided that it would be better to make a small charge to overcome these difficulties.

At the present time there are four permanent appointments for this work at Hamilton, Chatham, Stratford and Kemptville. The men now instead of travel ing on trains and busses as before drive their own cars for which mileage is paid. This makes it possible for them to carry all the necessary equipment, changes of clothing, rubber boots, stakes, instruments and other equipment which they were unable to carry before.

Even during the last few years of the so-called depression, interest in drainage work has been very well maintained. It dropped a little in 1932, but during 1933 lower tile prices and lower costs of machine work gave an added stimulus to the work and the season was an exceptionally busy one. In that year 509 farmers were given assistance with their drainage problems in one way and another; 217 actual surveys were made, and of these the work on 185 had been started or completed up to last fall. This is very satisfactory as it represents 84% of the work surveyed.

Inspection Work

It is very difficult to make any accurate estimate of the amount of drainage work that has been done in Ontario during one any season as the surveying done by the department does not represent the work done. A number of farmers do work themselves without having a survey. It is further difficult to get all the tile yards to give a report on the tile sold each year, largely perhaps because they do not keep very accurate records or perhaps, which is more important, is the fact that they do not consider it worth while to send in a report. There are in the neighborhood of 100 tile manufacturing plants and about 180 ditching machines in the Province. These, of course, have not all been actively enaged during the last few years in drainage work, but a good many of them, particularly those in Western Ontario and the Niagara district, have been kept in pretty steady operation.

Demonstrations

During the earlier years of the department's work when surveys were made, a surveying demonstration was given at the time the survey was made. Farmers of the district would be invited to attend and benefits and ways and means of doing drainage work were discussed. In 1912 the

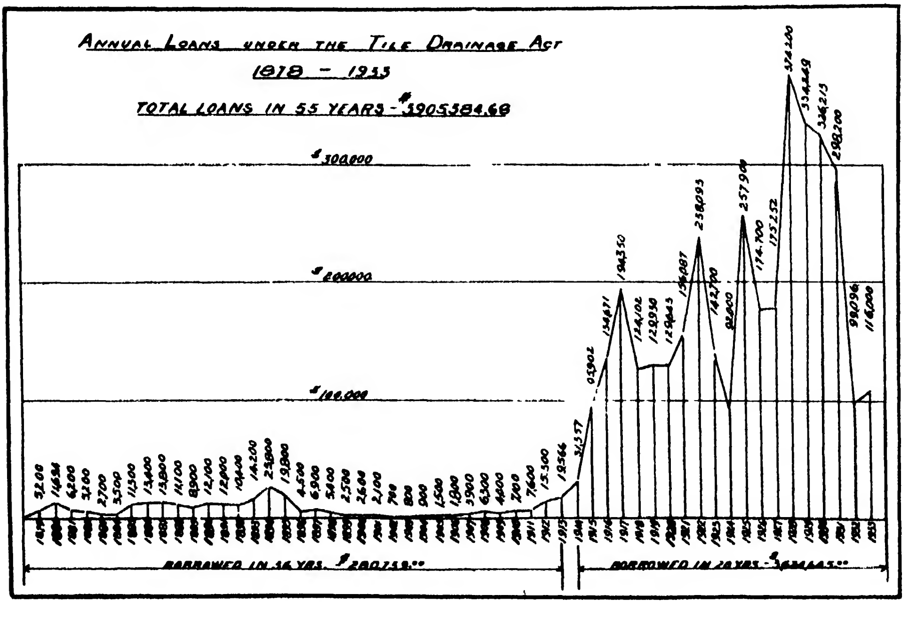
department purchased a machine of their own and during the next four years established drainage demonstration plots in various sections of the province. In all, 29 plots were put in. This gave the farmers a chance to see the ditching machine in operation. It also served to show what drainage would do on wet land and furthermore it gave the members of the department a chance to hold demonstrations and explain tile drainage to the interested farmers.

During the years 1925, '26, '27, '28 and '29 nine more plots were installed in Eastern Ontario, where only a few had been put in during the previous years. These have served to promote a good deal of activity in this section of the province.

The Tile Drainage Act

The Tile Drainage Act has been one of the most satisfactory pieces of legislation that has ever been passed by the provincial authorities. It was on the statute books long before the department took any interest in assisting the farmers with their drainage problems. Briefly, it makes possible the installation of tile without any serious financial outlay on the part of the farmer himself. The act has, of course, been amended from time to time as was necessary under changing conditions.

At the present time the government has set apart three million dollars of the Consolidated Revenue Funds of the Province to be used by the municipalities for drainage work. Each municipality can borrow as high as $200,000, and even $300,000 if the total assessment of the municipality is three million dollars or over. It is necessary for the municipality to pass a bylaw establishing a credit with the Provincial Government for whatever money they think their township might be able to use over a period of years. When this bylaw has been passed and the necessary



papers made out by the municipality and filed with the government they are in a position to accept applications from the farmers for loans for their drainage work. Usually, however, the bylaws are not considered until some of the farmers in the municipality become interested in drainage work and make an application for a loan.

The individual farmer can borrow 75% of the cost of his drainage work up to $2,000 per 100 acres or fraction thereof. He gets this over either a 10 or 20-year period at 5% interest and repays it annually in his taxes at the rate of $12 95 or $8 03 for every $100 borrowed, depending on whether he borrowed it under the 10- or 20-year scheme.

Up to the present time some eighty municipalities in the province have passed the bylaw and are making loans to their ratepayers for this work. This loan, I may say, has prior rights on a man's property and comes ahead of a first mortgage. Consequently the mortgagee must give his consent before a loan can be made. The municipality appoints an inspector who makes a report on the work that has been completed showing the total cost of the work, and 75% of this is calculated in preparing the necessary debenture for sale to the Provincial government. It is possible for a man doing drainage work to work out pretty well the 25% which he is required to furnish by drawing and spreading tile, backfilling the trenches, board of men, etc , so that it is possible for him to do drainage work without making any large cash outlay.

Provision is made for him to pay the loan off at any one time if he wishes, but he either makes his annual payments or retires the entire loan.

A STUDY OF THE BEHAVIOUR OF THE WATER TABLE IN UNDERDRAINED AND SURFACE-DRAINED RIVER VALLEY SOILS IN QUEBEC (A PROGRESS REPORT)[1]

Robert Millinchamp[2]

Macdonald College (McGill University) P.Q.

The chief agricultural producing areas of the province of Quebec lie in the valleys of the St. Lawrence, Ottawa, Gatineau, Chateauguay, Yamaska, St. Maurice, Saguenay and other smaller rivers.

Since the soils of these areas are largely of sedimentary origin they and their sub-soils consist mainly of various types of clayey formations. Because of their elevation, they are subjected not only to normal precipitation but also to the run-off from adjacent slopes, and, due to their level topography, satisfactory surface drainage is often difficult if not impossible.

In the past, before the day of the automobile, these areas enjoyed prosperity and found a good market in the larger cities, and to some extent in England, for their chief crop —timothy hay. In the course of time, however, as the taxi and truck replaced the "cabby" and horse drawn lorries, the market for timothy hay narrowed very materially. Accordingly it became necessary for our hay producers to adopt rotational farming, and in many districts this change is at present in progress.

Whether it was a matter of chance or design that timothy became the main crop of these areas, the early farmers of the St. Lawrence and other river valleys were extremely fortunate in the possession of a plant so splendidly adapted to the poor drainage conditions which are almost universal in these lands. Timothy seems to grow abundantly wherever there is a layer of 3 or 4 inches of good soil, and, so long as the saturation level was not nearer the surface than this during the growing season, a good crop was assured. With the introduction of rotational farming, with its deeper feeders and more frequent cultivations, these meagre depths of water-free soil proved entirely inadequate. While some of the gramineous crops will do fairly well, in favourable years, on land of indifferent drainage, clovers and alfalfas cannot be grown successfully under these conditions. The importance of these crops to successful diversified farming is universally recognized. The roots of clover and alfalfa penetrate to considerable depths in the sub-soil, but if the sub-soil is water-filled this root development is curtailed, with obvious results.

Figure 2 records the results of recent research on this phase of the subject and shows how root development is seriously hampered by free water in the soil.

The need for more abundant drainage has been apparent to the Department of Agriculture of the Province of Quebec for some years. About 1910, ditching machines were purchased by the government of the province for the purpose of demonstrating and assisting in the installation of farm drains. Drainage systems were installed on various farms in different

[1] Paper read before the Agricultural Engineering Group of the C.S.T.A. at Macdonald College, P.Q., June 26 and 27, 1934. Contribution from the Faculty of Agriculture of McGill University, Macdonald College, P.Q., Canada, Journal Series No. 61.

[2] Assistant in Agricultural Engineering.

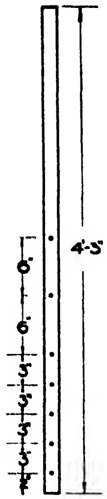


FIG 1-GAUGE PIPE SHOWING SPACING OF 3/16 PERFORATIONS

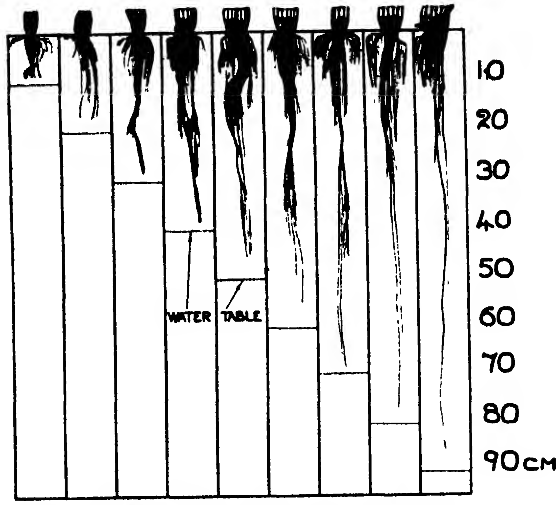


FIG 2-SHOWING HOW ROOT DEVELOPMENT IS CURTAILED BY SATURATION LEVEL IN SOIL
(COURTESY OF IMPERIAL BUREAU OF SOIL SCIENCE)

parts of the province to demonstrate to these communities the value of this form of land improvement. This work, of course, was not very extensive, having been done almost without expense to the farmer. Also, in 1920, there was placed on the statute books the "Drainage Act", which gives to municipalities the right to borrow money to be advanced to farmers for drainage purposes. Any farmer owning land which justifies the expenditure for a drainage system may call on his municipality to raise funds in this way for his purpose, but to the writer's knowledge the "Drainage Act" has never been put into use.

However, before this government-aided extension work could bear fruit, there came serious intervention in the form of the Great War, bringing with it high prices, scarcity of labour and consequent cessation of all drainage efforts. Since then the generally unsettled condition of agriculture, and more recently, the depression have prevented a resumption of interest in this form of land improvement.

With a view to the future needs of Quebec farmers, and after some years of observations of the performance of drains in various fields, it was felt that a study of underdrainage performance in the province was necessary. It was believed that possibly our soils and subsoils may contain factors not common to the experiences with tile drainage in Ontario and elsewhere. After some consideration, therefore, it was decided to establish a series of plots where influence of underdrains on the water table in our soils could be observed and recorded.

Experimental Work

Primarily this project is one of a study of the behaviour of the water table in drained and undrained adjacent fields. It is the hope that the following objectives can be reached:

1. To determine the extent to which drains, now installed, are effective in controlling the water table.

2. To determine optimum depth and spacing of tile drains.

3. To determine the physical characteristics of the soils and subsoils of our typical, heavy, river-valley lands.

4. To determine the economic value of underdrainage in our soils.

Four observation plots were located as follows:

1. Ste. Rosalie in Ste. Hyacinthe County.
2. Howick in Chateauguay County.
3. Ormstown in Chateauguay County.
4. Hudson Hts. in Vaudreuil County.

In each of these plots tile drains had been in operation for some years,

TABLE 1.—RESULTS OF MECHANICAL ANALYSIS OF SOILS

Location	Sample	Sand %	Silt %	Clay %	Loss on ignition %	Difference %
Hudson Heights	Surface	17 57	33 75	40 5	6 18	2 00
	Subsurface	8 68	31 00	51 0	6 65	2 67
	Subsoil	3 8	28 25	60 5	5 84	1 61
Ormstown	Surface	8 5	24 2	56 1	8 7	2 5
	Subsurface	10 5	16 6	64 2	7 87	0 83
	Subsoil	4 1	12 1	73 02	8 5	2 28
Howick	Surface	11 4	45 5	30 0	9 6	3.5
	Subsurface	5 2	37 0	49 0	6 58	2 22
	Subsoil	4 1	27 75	61 25	5 25	1 65
Ste. Rosalie	Surface	13 5	22 0	52 25	10 1	2 15
	Subsurface	2 6	4 25	84 0	6 77	2 38
	Subsoil	1 5	4 0	85 5	7 2	1 8

and adjacent to each there is available undrained land to serve as check areas. These plots seem to be typical of our river valley soils.

The equipment used was similar to that used by Schlick in his experiments and consisted of gauge pipes (Figure 1), lines of which were installed at right angles, between two lines of tiles, as shown in the accompanying graphs. The gauge pipes were made of $\frac{3}{4}''$ galvanized pipe 4′ 3″ long, with 3/16″ holes drilled through both sides and placed as shown on the diagram of the pipe.

The gauge pipes were placed at varying distances apart, depending upon the distance between the tile lines. Pipes were placed in check plots also, sufficiently far removed from the drained area to make available a water table not affected by the tile. These pipes were set in holes bored with a small soil auger and were placed so that about $2\frac{1}{2}$–3″ projected above the ground surface. After the pipes were set and the soil filled in around them, the elevations of the tops of the pipes were taken with a level and recorded.

The elevation of the water table was determined from measurements taken in the gauge pipes. The owners or operators of the farms on which the plots were located co-operated with the Department and at frequent

intervals read and recorded the distance from the top of each pipe to the level of the water inside it. A 3/8″ square graduated rod was provided for this purpose. From these readings and the predetermined elevations of the pipes, by subtraction, the elevation of the water table was calculated.

Soil Analysis

In co-operation with the Physics Department of Macdonald College mechanical analyses of the soils on each plot were made. The results of these tests are shown in Table 1.

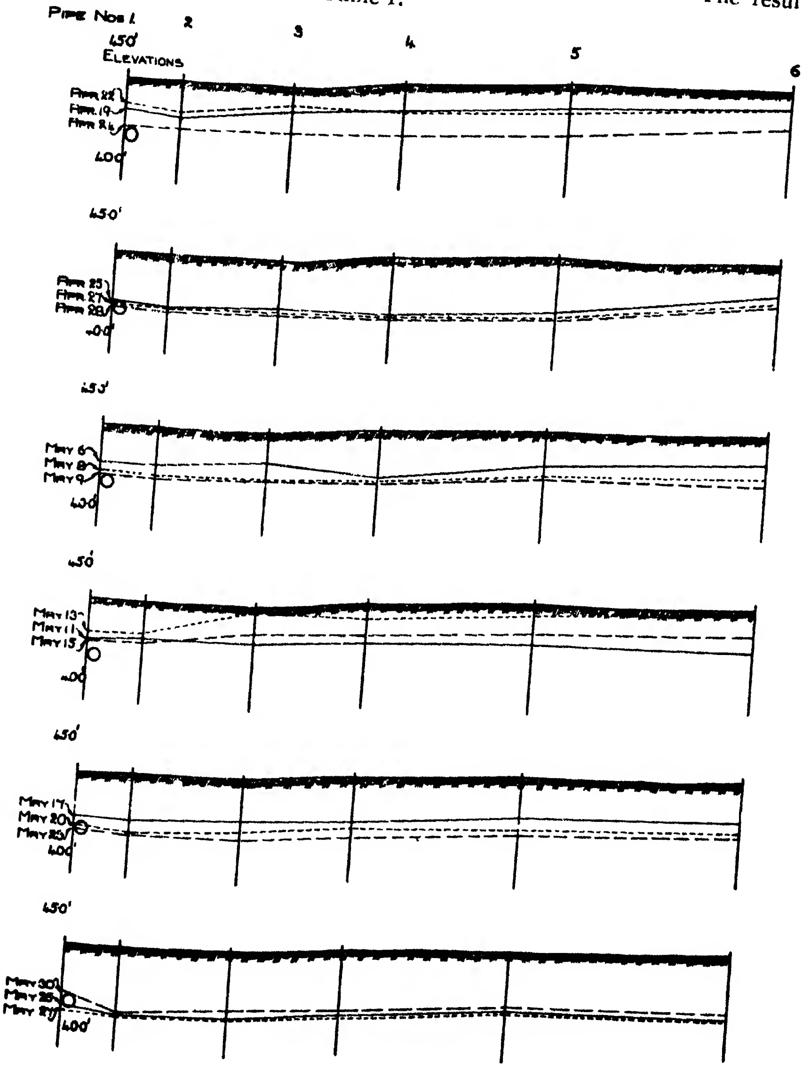


FIG. 3
GROUND WATER FLUCTUATION DIAGRAMS.
HUDSON HEIGHTS, QUE.

It will be noted that in each case the subsurface and subsoils are heavy clays.

Results

Little discussion need be given to results, as the accompanying graphs, typical of drainage conditions during periods when the saturation level is fairly high, indicate the elevations of the water table in drained and undrained plots for the given dates.

Hudson Heights Plot

It will be noted from the graph, Figure 3, that one line of tile only is installed on this plot, and it is located in the lowest part of the field. Ordinarily it might be expected that the water table would be nearer the surface in the lower land. The graphs show, however, that the water

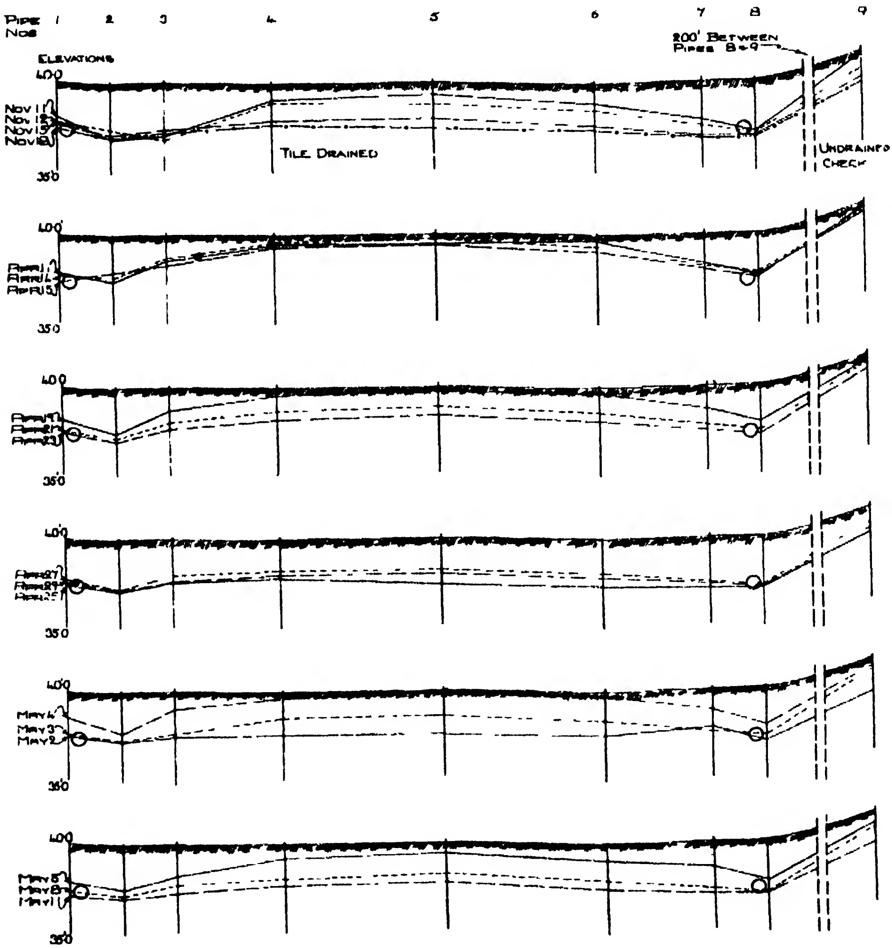


Fig 4
Ground Water Fluctuation Diagrams
Ormstown, Que.
1932-33

table is at its lowest near the tile line and rises more or less regularly to the last gauge pipe.

Ormstown Plot

On this plot, about twenty years ago, a tile drainage system was installed with drains at 65-foot intervals, and one entire field was drained. Gauge pipes were located between a pair of these drains, and two pipes were placed as checks in an adjoining undrained field 200 feet from the fence separating the two fields (See Figure 4.).

Two points of interest are brought out by this plot:

1. The extreme difference between the height of the water table in the drained and undrained fields.
2. The regular curve of the water table between the drains.

It is interesting to note the behaviour of the water table in this plot between the tile lines after heavy rains. While the saturation level rises almost to the surface during heavy rains, it goes down very quickly. The action of the drains in this field seems to be sufficiently prompt and dependable to exercise a very beneficial influence on crop yields.

Howick Plot

The gauge pipes in this plot were located in a field which was a considerable distance from the farmstead, and this, together with the fact that the owner of the farm was rather short of help at the time, resulted in few readings being taken.

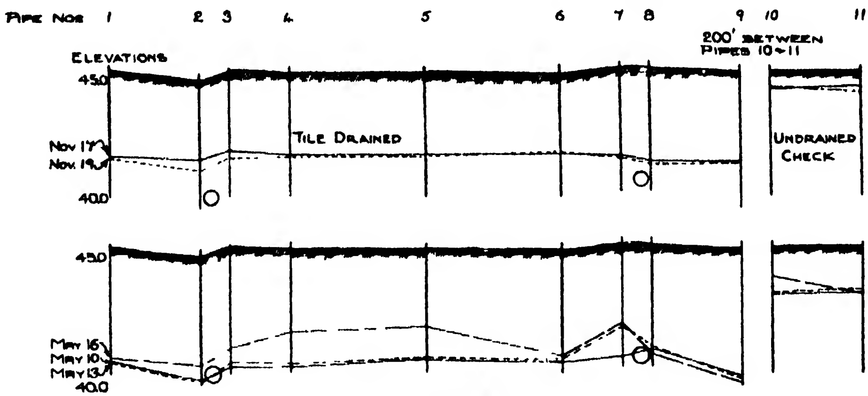


Fig. 5
Ground Water Fluctuation Diagrams
Howick, Que.

What readings were taken showed that the drains exercised a very definite influence on the water table during periods of excess soil moisture (Figure 5). An indication of the beneficial effects of underdrainage on this soil was brought to light on May 5, 1933, during a visit to the plot by the writer. On this date, the soil in the undrained check plot was saturated to within three inches of the surface, while in the tile-drained field the water table midway between the drains was 19″ below the surface, and 5 feet from the drains it was 30″ below the surface. Water stood on the surface in almost all dead-furrows and depressions in the check plot and the soil could only be described as very wet, while the owner was

preparing for spring tillage operations which could be begun in a few days on the drained land.

It should be mentioned also, that the land in the check plot was exceedingly well located for surface drainage, the gauge pipes in the check plot being located not over 200 feet from an open ditch about 7 feet deep located between the drained and undrained fields.

The water table in the drained field does not quite obey the general rule—that is, to form an arc towards the surface between the drains. Perhaps this can be explained by the fact that the drains on this farm have been in the ground for nearly 30 years and thus have had ample time to influence the structure of the soil between the drains.

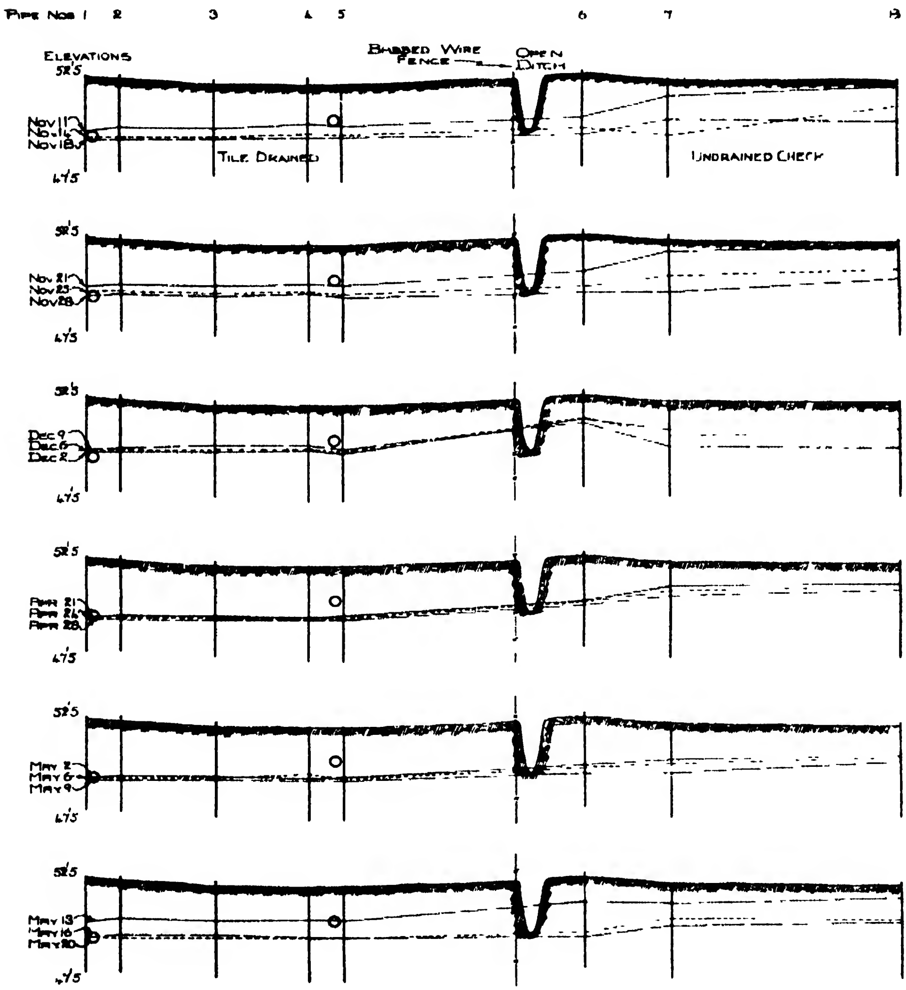


Fig 6
Ground Water Fluctuation Diagrams
for the Farm of the Coopérative Fédérée,
St Rosalie, Que
1932–1933

Ste. Rosalie Plot

When the gauge pipes were installed on this plot it was felt that here, if anywhere, the ability of tile drains to lower the water table would be tested. The soil was very plastic, being 89 5% clay, and the writer felt that movement of water in the soil would be very slow, if indeed the water could find its way to the tile at all. The water table in the check plot was influenced to some extent by the presence of an open ditch. This ditch was about 3 feet deep, and, since the gauge pipes were placed 8′, 25′ and 65′ respectively from it, it is reasonable to assume that the water table was affected by the presence of the ditch.

The graphs of early tests show a marked difference of elevation of water table in favour of the drained land (See Figure 6). The results in the fall of 1933 and spring 1934 do not show such a marked difference. During our visit to this plot in the fall of 1933, we found that the outlet ditch had been allowed to fill in, and there was considerable vegetation in the ditch. We believe that this hampered the discharge of the tiles. This belief was partially substantiated when, during a visit to the plot in the spring of 1934, it was found necessary to take up and replace several broken tiles. While the winter of 1933-34 was rather severe, experience has shown that frost injury to tile is caused only when water has been allowed to freeze in them, and we believe this to be the root of the trouble in this particular case.

In spite of the extremely heavy clay subsoil of this plot the drains exert a very beneficial influence on the water table, particularly during the saturation period of the year, from November to May.

SUMMARY

1. On land tested to date in these plots, tile drains have shown, definitely, their ability to lower the water table.

2. From the writer's observations and the farm owners' records (usually observation) crops grown on drained land are superior in quality and yield to those grown on undrained land.

3. Soils on which the plots were located showed medium to heavy clay subsoils.

4. Farm owners estimated that it was possible to get on the drained land about ten days earlier in the spring than on the undrained land.

Résumé

Une étude du comportement du niveau d'eau dans les sols égouttés au moyen du drainage et de l'égouttement de surface. R. Millinchamp, Collège de Macdonald, P.Q. D'une vallée de rivière dans le Québec.

Sur les parcelles où ces essais ont été conduits, les tuyaux de drainage ont montré très clairement qu'ils peuvent abaisser le niveau de l'eau. D'après les observations de l'auteur et les notes des propriétaires de ferme (généralement des observations) les récoltes cultivées sur terre drainée sont supérieures en qualité et en rendement à celles cultivées sur terre non-drainée. Les sols sur lesquels des parcelles étaient établies avaient des sous-sols d'argile lourds ou mi-lourds. Les propriétaires de ferme estimaient que l'on pouvait travailler la terre drainée environ dix jours plus tôt au printemps que la terre non drainée.

OAT SEEDLING DISEASES IN ONTARIO

I. THE OAT NEMATODE *HETERODERA SCHACHTII* SCHM.

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INTRODUCTION

A cereal root parasite of major importance, the oat strain of the nematode *Heterodera schachtii* Schm.,[2] has made its appearance in Ontario. This species which comprises several biologic races, has been known for many years in Europe where it occurs upon a variety of crop plants. The sugar beet race has for some time been present in the United States, and has been reported once (*1*) in Canada, but this is the first record of the occurrence of the oat race in North America.

During the summer of 1932, the Ontario Research Foundation was asked by farmers in South Simcoe County to investigate the cause of the repeated failure of their spring grain crops. Since the region has been settled for a comparatively long time and has always been more or less specialized to cereal farming, it was suspected that the exhaustion of soil nutrients might be responsible. Extensive soil tests, however, did not reveal anything upon which the blame might be placed and attention was then directed toward the investigation of root-inhabiting parasites.

The nematodes were first discovered in July, 1933, upon the roots of oat plants grown in oat-sick soil in the green house. A partial survey including fifteen fields in which the crops were very poor or patchy showed that nematodes were consistently found upon the roots of sick plants. It is not known how long this parasite has been present in the area, but farmers report that failures of spring grain crops have occurred for at least ten years, and it is now impossible to trace the original infestation.

LITERATURE

The literature dealing with this parasite has been well surveyed recently by Goodey (*6*) and a complete bibliography on the genus *Heterodera* has been issued by the Imperial Bureau of Agricultural Parasitology (*9*). *Heterodera schachtii* was first reported on oats and barley by Kuhn (*10*) in 1874, and Voight (*17*) in 1892 found that the oat and beet strains with which he worked were apparently specialized upon their respective hosts. Since that time various investigators have shown that the oat race is capable of attacking practically all the cereal crops, though Nilsson-Ehle (*11*) has indicated that some strains of barley are resistant. The oat race has been described in Germany, Holland, Norway, Sweden and Denmark. According to Davidson (*2*), *Heterodera schachtii* has probably been present since 1906 on cereals in South Australia, and Hickenbotham (*8*) correlated the presence of nematodes with "no growth" patches in barley and oats. The most recent work on this pest is given in the valuable account by Goffart (*5*) from Schleswig-Holstein.

[1] Research Fellows in Agriculture. During part of the period in which this investigation was under way, Dr. Putnam was Assistant in the Department of Botany, University of Toronto.

[2] We are indebted to Dr. Gerald Thorne, Associate Nematologist of the U. S. D. A., for confirmation of the identification of this parasite.

A nematode infesting the roots of wheat in Saskatchewan was reported by Russell (*12*), but it has been described by Thorne (*15*) as a new species, *Heterodera punctata* Thorne.

Brown (*1*) reported the presence of the sugar beet race in a single field in Western Ontario, but it has not since been found anywhere else in Canada.

SYMPTOMS

In the outbreak under consideration, total as well as partial crop failures have been noted in the case of both oats and barley, but as a rule the oat crop suffered much more heavily. In fields of mixed grain it has often been observed that the oats have been a complete failure and that the grain harvested was nearly all barley. In view of the fact that the disease is much more noticeable on oats, most of the discussion on symptoms will be based upon the appearance of diseased oat plants.

It is possible to distinguish the diseased plants about two weeks after they appear above ground. They do not appear to be growing at a normal rate and the crop is often spoken of as "standing still". In addition, the plants have a "staring" appearance; that is, the leaves, of which there are usually two at this stage, stand stiffly erect with somewhat inrolled margins. The most striking symptom and the one which has locally given to the disease the name of "red leaf", is the brick red tinge which rapidly spreads over a patch or a field when the plants are about three weeks old. The discolouration begins at the tip of the first leaf, the whole of which then gradually becomes brick red and eventually withers. In many cases the second leaf also becomes discoloured, and sometimes even the upper portion of the third leaf.

While, in the main, the colour of the leaves on diseased seedlings may be described as brick red, there is some evidence that the supply of available nutrients may influence the appearance and severity of the symptoms. Increasing the available phosphorus in the soil by the application of acid phosphate imparts a distinct orange shade to the leaves; where muriate

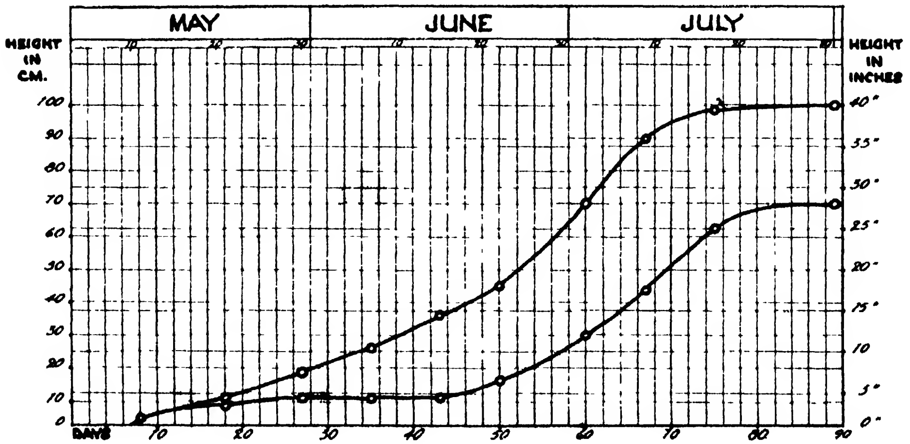

FIGURE 1.—Chart showing comparative average heights of healthy and diseased oat plants throughout the growing season of 1934.

of potash was applied alone, a purplish shade was evident; and with a moderate application of ammonium sulphate the discolouration was inclined to be yellowish. The greatest effect was obtained when a combination of ammonium sulphate and superphosphate was applied. The "red leaf" condition was much intensified and rapidly involved all the leaves on the plants which were very much stunted, and in fact, many of them were killed outright.

The "red leaf" stage usually lasts about a week or ten days, after which the plants put out new green leaves, and the discoloured ones wither and drop. The growth of the plant, however, has received a check from which it never recovers. The chart in Figure 1 shows that diseased plants are always shorter and mature later than healthy ones In dry years badly diseased plants never come into head at all, while in years of moderate rainfall such as 1934, a fair crop may be harvested even in spite of a moderate infestation.

Tillering, while never very abundant under ordinary field conditions, is practically non-existant in diseased plants The panicles seldom have more than half the ordinary number of spikelets and the grain is poorly filled, many florets being empty. The culms are much slimmer and weaker in diseased plants. Except in special cases, however, very few plants actually succumb, though one wonders how they manage to exist. The typical mature plant in a badly infested patch (Figure 2) is about one foot or fifteen inches in height, bearing a head of from one to five unfilled grains.

The general appearance of infested fields deserves some mention. Only a few fields are uniformly badly infested, although there were some in which it was impossible to find a healthy plant, even in 1934. Infested fields usually have a patchy appearance (Figure 3) which becomes greatly intensified as the season advances because of the abundant growth of weeds, particularly of sow

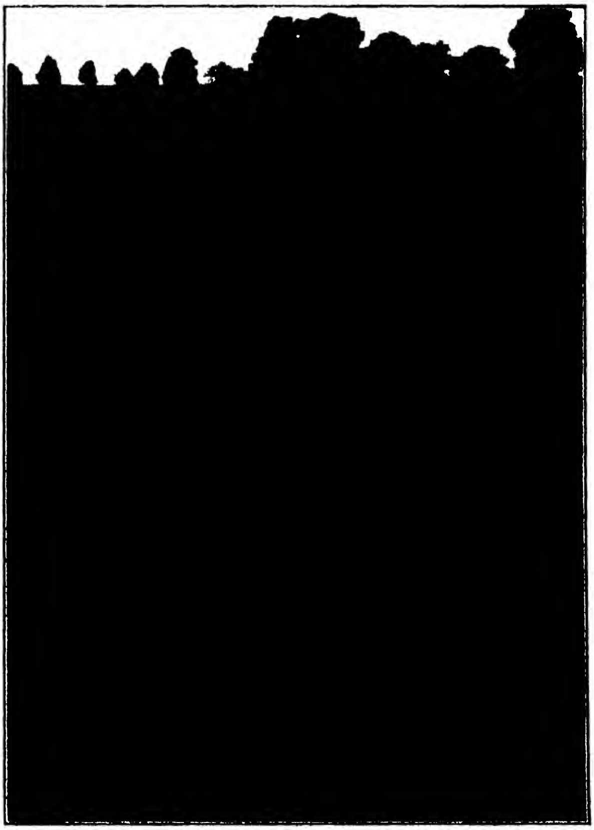

FIGURE 2.—Mature oat plants in a badly infested patch (1933) This field contained only this one diseased patch in both 1933 and 1934

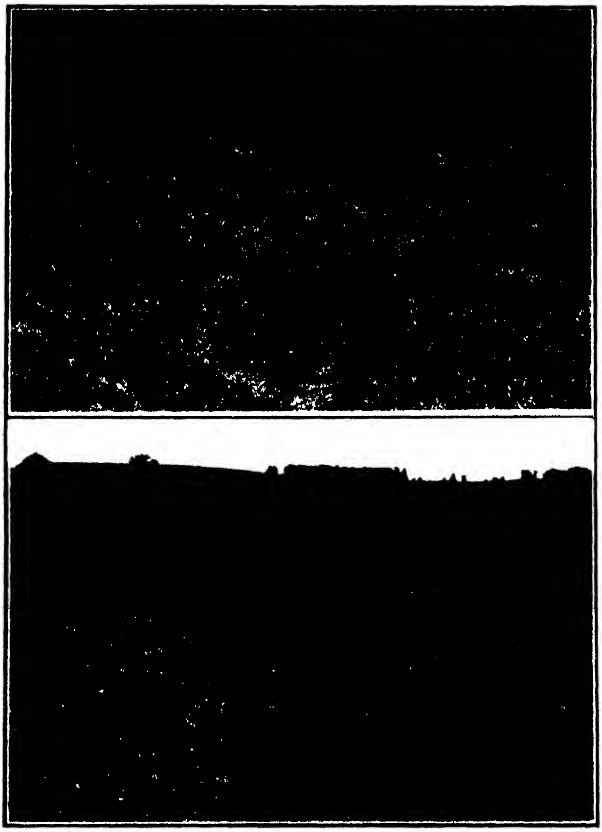

FIGURE 3 -- The appearance of a typically diseased field in June, 1933.

thistle. Sometimes a field may be found in which there is only one patch, while in others there may be a great many. Patches may vary in size from a few feet to several rods in diameter. Sometimes they are elliptical or oblong with their long axes parallel to the prevailing direction of cultivation. It is interesting to note that Hickenbotham (*8*) makes the same observation with respect to the "no-growth patches" associated with the presence of this parasite in Australia.

It has been repeatedly observed, both in 1933 and 1934, that in diseased patches, one drill row may be much poorer than the others and that such poor drill rows apparently extend farther into the better areas surrounding the patches. Examination of adjoining rows revealed that in the case of the better plants the seed had been sown more deeply, while in the poorer drill row it had been covered with only an inch or so of soil. In one badly infested field it was observed that the oat plants were noticeably taller in the wheel marks of the tractor which had been used in cultivation. The result of soil compression in this case was probably the same as that of deep sowing, namely, to make available a more dependable supply of water to the struggling plant.

Striking as may be the appearance of the aerial parts of diseased plants, the difference between healthy and diseased root systems is even more marked and more specific, and is quite evident in carefully washed seedlings long before any difference is discernible in the appearance of the leaves.

The examination of seedling plants some ten or twelve days after they appear through the soil does not disclose any great difference in the aerial parts, but the difference in the roots may be very great. The seminal root system of a diseased plant is usually only a fraction of the length of that of healthy plants of the same age. Whereas the healthy roots were long,

PLATE I. 1. A comparison of healthy and diseased oat root systems in the early stage of growth. (×[illegible]) 2. Diseased oat plants twenty-four days from date of sowing. (×$\frac{1}{2}$) 3. Diseased oat plants six weeks from date of sowing. (×$\frac{1}{2}$) 4. A single root from a diseased plant, showing the excessive branching. (×12)

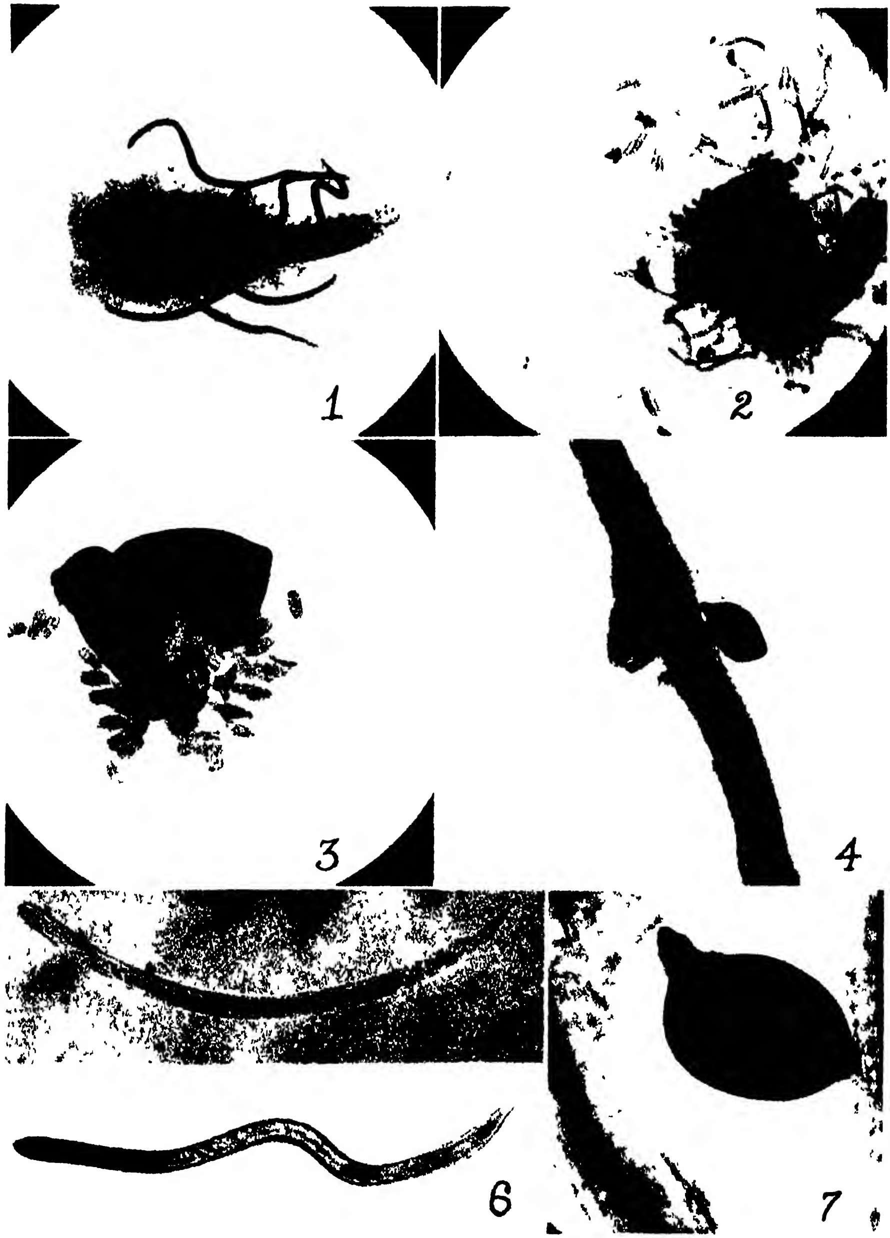

PLATE II.—1. An oat root tip infested with nematode larvae (×37). 2. First stage larvae obtained by crushing a brown cyst (×37). 3. A brown cyst containing eggs, each with a coiled larva inside (×37). 4. Mature female nematodes (white cysts) attached to an oat root (×21). 5. A first stage larva, just released from the brown cyst (×150). 6. Nematode larva obtained by dissecting out an infested root tip (×150). 7. Mature female nematode detached from root. (×47).

slim, white and almost unbranched, the diseased roots were short, crooked, thickened, discoloured and beset with short stubby laterals (Plate I, 1). The excessive branching imparts the matted appearance that is always shown by investigators as a typical symptom of the disease. The texture of the diseased roots is characteristically crisp, and the colour even after washing, is a dirty yellow or yellowish brown. It is usual to find that the nodal or crown roots appear much more quickly than they do on healthy plants, thus keeping the root development close to the surface.

A week or so later, when the "red leaf" stage was at its peak, it was found that an abundance of short lateral rootlets had been put out (Plate I, 2), giving the seminal roots a thickened, matted appearance, though very little increase in length had taken place. The nodal roots had grown somewhat in length but were also becoming thickened at the tips and studded with short lateral branches. It was found that for a period of about three weeks the diseased plant was not able to increase effectively its area of occupation in the soil and in consequence of this limited capacity for absorption the aerial development was restricted to a small fraction of that of a healthy plant

At various times during the period of the most marked symptom expression, that is, from about three to six weeks after planting, collections of both healthy and diseased plants were made, care being taken to preserve the root systems intact The measurements made on some of these plants collected from plots to which no artificial fertilizers were added, are presented in Table I and serve to compare the growth of healthy and diseased plants both above and below the surface of the soil.

TABLE 1 —COMPARATIVE AVERAGE MEASUREMENTS OF DISEASED AND HEALTHY OAT SEEDLINGS AT DIFFERENT AGES

Age in days	Number of plants		Number of leaves	Height of plant	Seminal roots		Nodal roots	
	Healthy	Diseased			Ave. no per plant	Ave length	Ave no per plant	Ave. length
				cm		cm.		cm.
18		5	2	9 4	5 0	3 2	2 8	3 0
	15		2	11 7	4 4	7 8	1 9	0 4
27		7	3	10 5	4 7	3 8	4 1	5 3
	5		4	18 5	4 5	9 8	4 0	5 0
35		11	3	10 6	5 0	4 1	3 5	4 5
	3		6	26 0	5 0	12 5	4 0	9 5
43		6	4	10 3	4 5	6 9	3 6	6 4
	2		7	36 5	5 0	15 0	6 0	11 5

In order to compare the root systems of mature plants, excavations were made in the centre of a severely diseased patch and in a healthy field nearby where conditions were otherwise similar. It was found that the roots of diseased plants never attain any great length. The following description of a typically diseased root system was written at the time the plants were excavated:

"August 10. Total length of seminal root system, 4½ inches, cortex mostly missing but stele apparently intact. There are five roots, extensively branched with short, swollen, stubby, matted laterals, and with many nematode cysts adhering or black scars indicating where they have dropped off.

The first nodal roots are about the same length and are similarly clubbed and distorted.

The main bulk of the root system consists of six secondaries and their numerous short, matted branches, with a total length of about ten inches and from 1/25 to 1/50 of the bulk of a normal root system. There are a great many brown cysts adhering to the secondary roots, and in addition, there are numerous red and brown fungal lesions. The roots are all in the surface soil and do not extend below plow depth."

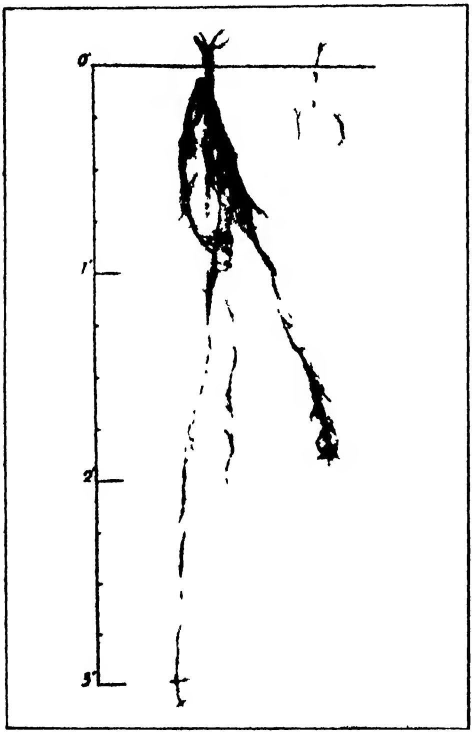

FIGURE 4 Pressed specimens of typically healthy and diseased mature oat root systems, excavated August, 1934.

In contrast to this, healthy plants at maturity have sound apparently functional, seminal root systems, which may penetrate to a depth of 14 inches (350 mm.). The secondary roots may attain a depth of over 3 feet with enough of them of sufficient length to provide a good working depth of two feet. The illustration in Figure 4 gives a good idea of the difference in root development.

Barley is seldom so heavily attacked as oats and is hence often able to produce a fair crop. In severe cases, however, the same patchy appearance, coupled with extreme weediness, is seen in the field. The young seedlings are stunted and the roots are short and distorted though not always so matted as those of oats. The leaves of the diseased barley plants invariably turn yellow rather than red, but they wither and drop in about the same length of time.

ETIOLOGY

Nematodes were first observed during the summer of 1933, and in a preliminary survey of fifteen fields, cysts were found on the roots of stunted plants in all cases. Since in addition large numbers of fungal lesions were found on the roots of all diseased plants, it was felt advisable to investigate the fungus flora of these roots. Accordingly, a number of isolations were made and pure cultures secured. Certain of those which appeared most consistently were then selected for pathogenicity tests.

Preliminary *in vitro* tests were made upon oat seedlings grown aseptically in flasks of Pfeffer agar. Inoculations were made, using two species of *Pythium*, two strains of *Ramularia* and one strain of *Fusarium*. All five were able quite quickly to penetrate and cause lesions upon the oat roots under the conditions of the experiment.

Further pathogenicity tests were then attempted, using soil brought from the affected area, steam sterilized and placed in pots on the greenhouse bench. Sufficient inoculum was obtained by growing pure cultures of the above fungi on autoclaved flasks of oats; this was added to the soil at the time the seeds were sown It was found that the *Pythium* species were capable of giving a quite definite check to the development of the root system. The strains of *Ramularia* and *Fusarium* were able to produce numerous lesions on the roots, somewhat similar to those observed in the field. All five fungi were easily re-isolated from these diseased roots. In no case, however, did the general appearance of the root system, or the growth habit of the aerial parts of the plants, duplicate the symptoms observed in the field.

In addition to the pathogenicity tests with the various fungi isolated from oat roots, an attempt was made to determine which parasite, or parasites, first effected an entry into the roots Two sets of greenhouse experiments were included in this series: one in which the soil from an infested field was placed in pots on the bench under ordinary conditions, and one in which the soil was placed in metal containers immersed in Wisconsin constant temperature tanks. It was thus possible to hold the latter at different temperatures and to keep them adjusted to various soil moistures. Oats were planted and periodic examinations of the roots were made from the time of germination. The first fungus to gain entrance to the oat roots, except in very dry soil, was always *Asterocystis radicis*, which has been reported by Vanterpool (*16*) as being in constant association with diseased oat roots. In moist soil (over 30% based on constant weight at 90° C) it was usually in advance of the nematode but in moderately dry soil (19%–26%) the nematode was always the first parasite to enter the root tips, and in very dry soils (12% 15%) *Asterocystis* was not found although nematodes were in abundance. In moist soils the second series of invaders were usually *Pythium* sp. and in the dryer soils, *Fusarium* or other Fungi Imperfecti It was only in the dryer soils that anything resembling the conditions of the roots in the field could be demonstrated. Here the roots were short and stubby, and after a month were found to have fairly large numbers of nematode cysts adhering.

In May 1934, a similar series of observations was carried out in the field. The soil was at no time found to contain as much moisture as was maintained in the wettest greenhouse conditions, but ran from 20%-24%. On the third day after planting, sprouted oats were dug up and examined microscopically for parasites. Nematodes were again found to be the first entrants into young oat roots, often being found before the radicle was more than one-quarter of an inch long. At this time no fungus of any kind could be seen in the roots. Out of about fifty roots from an infested field examined on the fourteenth day after planting, all contained nematodes but in only one was any fungus seen, which in this case was a *Pythium*. Oat roots in which no nematodes were found did not branch

early but continued to grow downward for several inches, while roots only half an inch long which had been invaded by nematodes had already put forth from six to twelve lateral branches (Plate I, 4).

LIFE HISTORY OF *HETERODERA SCHACHTII*

Nematode larvae are easily demonstrated in the root tips of infested seedlings by crushing the unstained tissue in a drop of water on a microscope slide, and examining under low power. In order to determine more accurately the number and the position of the worms in the tissue, some method of staining had to be employed. It was found that boiling for a minute in lactophenol to which had been added either cotton blue or acid fuchsin gave excellent results. By this means a total of thirty-three nematodes were found in one root which was less than 1.5 cm. in length, taken from an oat seedling in May, fourteen days after planting. This short root had already ten lateral branches, and all but one of them contained nematodes. The larvae are invariably found with their heads toward the tip of the root (see Plate II, 1). As many as sixteen nematodes have been observed in a single root tip less than two millimeters in length. They seem to prefer the meristematic regions, but are also to be found in small numbers throughout the cortex, but not in the stele.

When first found in the root tips, the larvae are from .55 mm. to .60 mm. in length, with a rather bluntly rounded head containing the buccal spear or stylet which can usually be fairly easily seen (Plate II, 5). The tail in larval stages is pointed. First stage larvae observed when emerging from the eggs and still within the cysts measured .53 mm. to .55 mm. (Plate II, 2). For a period of about three or four weeks the larvae remain typically worm-like (Plate II, 6), though undergoing one moult during this time and increasing somewhat in length and thickness. At about four weeks from the time of entering the root, the nematodes become somewhat flask-shaped bodies in which the adults may be seen. From this time on the development of the two sexes is quite different. By the middle of June, or about five weeks after planting, mature female nematodes may be found as somewhat swollen, curved bodies, partially protruding through the epidermis of the root. Mature males, slightly over 1 mm. long and typically worm-like, were found free in the soil about the roots at the same time. A week later white, lemon shaped, female bodies ranging in size from .6 mm. to .9 mm. long by about .4 mm. to .6 mm. in width were found containing eggs. They are attached to the root by the head end (Plate II, 4), around which is to be seen the remains of the last moulted cuticle (Plate II, 7).

The female nematodes for the most part remained white until well into July when they changed gradually into brown cysts. The eggs (Plate II, 3) average about $115\mu \times 49\mu$ and are at first unsegmented but by August first some of them were observed to contain fully formed larvae though no hatching had taken place. From September till freeze-up, however, there could be obtained from the soil fresh cysts which contained from one to two dozen first stage larvae, as well as others in the act of emerging from the egg. Nematode cysts are easily obtained by flotation or by centrifuging a suspension of soil in water.

In the fall, first stage larvae have been found in the roots of volunteer oats and barley and in fall wheat. Periodic examinations of the roots of fall-sown cereals were made from seeding time in September until freeze-up late in November but no mature female nematodes were found although more time had elapsed since planting than was the case with spring sown grains.

MIGRATION OF LARVAE

In order to test the migratory and infective powers of the nematode, the following preliminary experiment was performed. A wooden box about eight inches in depth from which the bottom had been removed was bedded in the subsoil of a field and divided into two compartments by means of a fine wire screen Into one compartment was put soil from a badly infested field and into the other was put soil from a field which was known to be free from the disease. Oats were planted in the nematode free soil while the infested soil was left unplanted. In order to provide a control, two other compartments of the same type were provided, in both of which non-infested soil was placed and one of them planted with oats.

No apparent difference in the aerial parts of these two lots of plants could be noted, but when, late in the season, the oats were dug up and examined, it was found that the plants grown in non-infested soil in juxtaposition to infested soil had a moderate number of nematodes attached to the roots, and there was in addition a certain amount of typical root distortion. In the check lot there were no nematodes and no root distortion was found. The distance travelled by the nematodes across non-infested soil was about eight inches. This distance is quite short when compared with the results of similar experiments quoted by Goodey (*6*).

DISPERSAL

In addition to the actual migration of the larvae for short distances, there are other, and perhaps more effective, ways by which the parasite may be spread The heavy soil is very tenacious and clings to the wheels of carts, implements, tractors, etc., the feet of animals and workers and in this way the parasites may be carried to new fields, and indeed, to entirely new localities. The brown cysts are light and float easily in water and are probably often spread in this way. The most thoroughly infested areas under observation all happen to be within reach of the flood waters of one or two small streams which must have been instrumental in spreading the infestation. Since no soil blowing is ever experienced in the district, wind is probably not an agent of dissemination in this case.

EFFECTS OF LOW TEMPERATURE

It has been mentioned that the infestation was in general not so bad in 1934 as it was in the previous year and a number of observations in the field point to the conclusion that the extremely low temperatures of the previous winter were unfavourable to the nematode. In a number of cases, fields which were total failures in 1933 had only mild or patchy infestations in 1934. In other cases, the infestations were restricted to definite zones or belts. These belts were usually in the lee of a hedge or a fence or in a sheltered hollow and in such a position that heavy snow drifts

had lain there during the winter. Figure 5 shows a field which was a total failure in 1933 but which is producing a good stand during the current year except for the belt along the left side which lies directly inside, and to the east, of a heavy rail fence. This difference was noticeable all through the season, and root examination showed that nematodes were abundant in this zone while not nearly so many were found in the rest of the field.

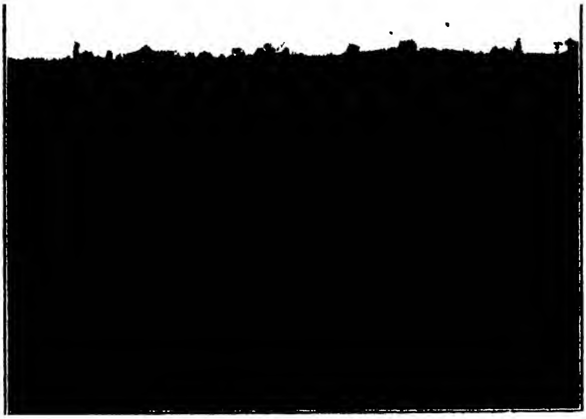

FIGURE 5.—Photograph of on oat field on June 12, 1934, showing a belt af diseased plants in the lee of a rail fence which stands just beyond the left of the picture. Note also the two weak drills which did not receive any fertilizer due to the clogging of the fertilizer attachment.

HOST RANGE

The Imperial Bureau of Agricultural Parasitology (*9*) lists 13 species of the Gramineae, and Goodey (*6*) lists 14 species which are attacked by *Heterodera schachtii*. During this investigation the mature female cysts have been found attached to the roots of the following plants: Oats, *Avena sativa* L ; wild oats, *Avena fatua* L ; barley, *Hordeum vulgare* L.; six-rowed barley, *Hordeum distichon* L.; wheat, *Triticum vulgare* Vill., both fall and spring sown varieties; speltz, *Triticum spelta* L.; and chess, *Bromus secalinus* L. Of these, wild oats, speltz and chess are not listed in either of the above publications Up to the present, no plants outside of the grass family have been found to be attacked by this strain of the parasite.

DISTRIBUTION IN RELATION TO SOIL TYPE

During the season of 1934 a complete field-to-field survey was made of the district The roots of the oat and barley crops were examined for the presence of nematodes and the fields were classified according to the degree of infestation, taking into account both the condition of the crop and the prevalence of nematode cysts on the roots. In South Simcoe county a total of 137 infested spring grain fields were found, located on 74 different farms which are fairly well concentrated within an area of about 30 square miles in the townships of Tecumseth and West Gwillimbury. In addition, two infested fields were found in Uxbridge township in Ontario county Of the total of 139 infested fields found in 1934, 30 were classed as severely infested, 40 as having medium infestation, and the remaining 69 as only mildly infested.

It is very interesting to note that nematode infestation seems closely correlated with the type of soil. In general, there are only two types of soil in the particular district though in places there is necessarily a transition zone where they grade into one another.

On the hills is found a light, stony or gravelly loam developed on morainic drift. It is naturally well drained and is neutral to alkaline in reaction. It is fairly low in organic matter but moderately well supplied with mineral nutrients. In the lower areas the soil is a silty clay loam. The topography is rolling, giving fair natural drainage. Much of it is underdrained, especially up the hollows and into springy spots. In many places, particularly on the slopes, it has been subject to erosion thus exposing the highly calcarious parent material. However, free lime carbonate occurs consistently even in the surface layers, making it a strongly alkaline soil. The pH is about 8 2 or 8 3. It is fairly well supplied with available nitrogen and potash but it is quite deficient in available phosphorus. It contains a moderate organic matter content. Detailed investigations of both soil types are now in progress and will be reported on later. The accompanying map (Figure 6) shows the distribution of the infested fields in relation to the soil type. Of the 137 fields only seven were found on the lighter soil and none of them were classed as severe. An equal number of infestations were found on transition soils; the remainder, or 90%,

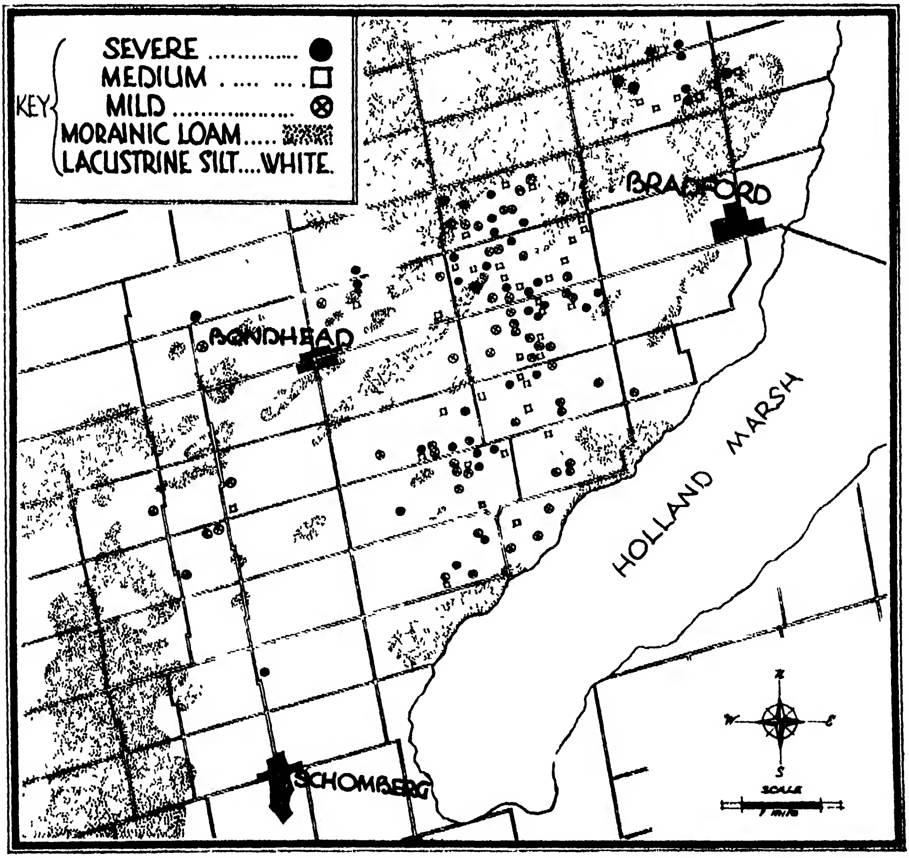

FIGURE 6.—Map of the district in South Simcoe county showing the location of all the grain fields found to be infested with the oat nematode in 1934, together with the distribution of the two chief soil types.

including all the severely infested fields, were found on the silty clay loam of the lower areas.

This type of soil covers a much larger area than that shown in the map. The silt deposits were evidently laid down in a glacial lake which lay between an ice front to the north and the high land to the south and are found almost continuously in an irregular belt extending from Creemore and Collingwood to Peterborough and Rice Lake. Associated sands and loamy soils form intervening areas in the old lake bed, but there are at least 70,000 acres of this particular type of silty clay loam, all of which must be regarded as a potential habitat for the oat nematode.

According to Russell[3] "the soil in the district where we commonly find *Heterodera punctata* Thorne is a park belt medium loam of morainic origin with a pH of about 7 2 to 8 0. The calcareous layer varies in depth in different parts of the district but is usually fairly near the surface." It would seem that this soil is somewhat lighter in texture than that described above.

The field at Glencoe in which Brown (*1*) found the sugar beet nematode was visited by the writers and found to be located on a Brookston clay loam, which is also an alkaline soil

These facts concerning the types of infested soil are mentioned because in European literature it is usually reported that the lighter types of soil are more favourable to the parasite. According to Goffart[4] the distribution of the oat nematode is generally on morainic light sandy loams and on the lighter marsh soils along the coast These soils are quite acid, ranging from pH 5 0–6 5. They have not become established on heavy clay soils nor on soils having a strongly alkaline reaction. The reverse would seem to be the case under Ontario conditions, for, while nematodes are found in both a light and a heavy type of soil, they are much more common and troublesome in the latter It has been noted several times in fields where both types of soil occurred that the infestation was present only in the part of the field located on the heavy soil. The reason for this is not known but it is hoped that detailed investigation of both types of soil may provide a clue.

CONTROL MEASURES

The control of a parasite like *Heterodera schachtii* may be attempted either by direct or indirect methods. Under direct methods are to be included all attempts at soil sterilization Indirect control methods may have one of the following purposes: (a) the stimulation of the plant to the point where it will produce a crop in spite of the infestation; (b) the elimination of the pathogen by dropping all susceptible crops from the rotation for a sufficient length of time; (c) the production of resistant varieties.

FIELD EXPERIMENTS

A. Chemical Disinfectants

The effectiveness of some of the cheaper substances, which have at various times been recommended as soil disinfectants, was tested in an infested field. A number of 1/100 acre plots were laid out in such a way

[3] In a personal communication of July 1934.

[4] In a personal communication of December 1934.

that each treated plot was provided with two adjacent untreated controls. The following treatments were carried out in duplicate.

Sulphur, 500 lbs. per acre and 1000 lbs. per acre.
Formaldehyde, ¼%, ½% and 1%; .75 qts. per sq. ft.
Acetic acid, 1 2% and 2.4%; .75 qts per sq. ft.
Pyroligneous acid, 1.5% and 3% .75 qts per sq. ft.

In addition, a commercial product containing cresylic acid of an unknown strength was used at the rate recommended by its manufacturer.

The field to which these treatments were applied turned out to be only mildly infested over most of its area and so produced a very fair crop. The application of sulphur failed to make any difference in the degree of nematode infestation as compared with the adjoining check plots. It also failed to destroy the strongly alkaline soil reaction. It had, especially in the case of the heavier applications, a distinctly detrimental effect upon the growth of the plants themselves.

There was no significant difference in the infestation in the 1% formalin plots and none at all in the case of the other treatments used. Even in the case of the 2 4% acetic acid where the ground was white with the deposit of calcium acetate, the soil reaction still remained strongly alkaline.

B. Fertilizer Tests

During the season of 1934, rather comprehensive fertilizer experiments were carried out on fields in the infested area in order to see if the seedling plants could be so stimulated that they would be able to overcome the attack of soil inhabiting parasites. The experiments were not designed as yield tests and hence were not replicated. Because of the patchy nature of the infestation, large plots of approximately one acre were used in the hope that several badly infested patches would be included in each plot. The following set of treatments was laid down in each of two fields in the area, the two farms being about four miles distant from one another.

10 tons per acre stable manure
20 tons per acre stable manure
400 lbs. per acre 2-12-6 fertilizer
250 lbs. per acre 20% superphosphate
50 lbs. per acre muriate of potash
40 lbs. per acre sulphate of ammonia
400 lbs. per acre 0-12-6 fertilizer
400 lbs. per acre 2-12-0 fertilizer
400 lbs. per acre 2-0-6 fertilizer

Three check plots were also provided in each field. The fertilizers were all hand mixed and applied with a combination grain and fertilizer drill. The single chemicals were mixed with an adequate amount of sand filler and applied in the same way.

One of these fields was plowed up about the middle of June because it was by that time, evidently, the most uniformly badly infested field in the district, and the weeds had obtained such a start that it was in many places almost impossible to see the oat plants. The other field was seeded down to sweet clover and was not plowed up, but the badly infested areas, which included about half the field, were cut over early in July in order to prevent the weed crop from going to seed.

The field which turned out to be so uniformly infested was sown on May 11 and was plowed under on June 14. At that time complete notes were taken and a number of plants were collected from each plot, care being taken to preserve the complete root system of each seedling. The following table compares the averages of the measurements made on this collection together with those of healthy control plants of the same age obtained from an adjoining farm.

TABLE 2.—THE EFFECT OF FERTILIZER TREATMENTS UPON THE GROWTH OF OAT SEEDLINGS INFECTED WITH *Heterodera schachtii*, DURING THE FIRST FIVE WEEKS

Plot No.	Treatment: Fertilizer used per acre	Number of leaves per plant	Height of plant in cm.	Number of seminal roots	Length of seminal roots in cm.	Number of nodal roots	Length of nodal roots in cm.
0	Healthy control	6 0	26 0	5 0	12 5	4 0	9 5
1	Diseased control	3 0	10 6	5 0	4 1	3 5	4 5
2	10 tons stable manure	3 4	12 4	4 8	5 8	4 8	5 9
3	20 tons stable manure	4 0	15 5	4 0	6 5	3 8	4 9
4	400 lbs. 2-12-6	4 0	17 0	4 6	6 5	4 0	3 5
5	250 lbs superphosphate	4 0	16 3	3 8	6 8	3 5	5.4
6	50 lbs muriate of potash	3 6	11 6	3 2	6 7	3 0	4.4
7	40 lbs. ammonium sulphate	2 7	11 4	3 6	2 9	4 3	3 1
8	400 lbs. 0-12-6	4 0	17 3	4 5	4 8	5 5	4 7
9	400 lbs. 2-12-0	3 1	10 5	4 4	1 0	2 2	1 7
10	400 lbs. 2-0-6	4 0	15 0	4 0	5 3	4.0	4 3

It will be seen immediately that no fertilizer treatment is able to produce plants comparable to the healthy controls. In general the best response was obtained from the use of complete fertilizer although superphosphate alone gave almost equal results. No benefit was received from the application of ammonium sulphate, and very little from muriate of potash. It is interesting to note that the plot receiving the combination of ammonium sulphate and superphosphate was by all odds the poorest looking plot in either of the experimental fields. The leaf area on almost all of the plants was completely destroyed and many of the plants, especially in the heavily infested field, died outright. The experiment illustrates the need for research into the effects of various commercial fertilizer substances when applied to such types of soil, entirely apart from the complicating factors arising from a diseased condition.

In view of the pronounced phosphorus deficiency found in this type of soil, and the ability of calcareous soils in general to "fix" phosphorus in an unavailable form, another experiment was planned in the hope of finding some level at which the beneficial effects of available phosphorus would offset the attack of the root parasites. In a third experimental field a series of varying amounts of superphosphate were applied, ranging from 50 lbs. to 1500 lbs. per acre.

In general the degree of infestation made more difference to the appearance of the field than did the amount of fertilizer applied. In badly infested patches the highly fertilized portions were little better than the

unfertilized checks; while, where there was less infestation, a considerable improvement could be noticed. The infestation of this field was of such a patchy nature that comparative data could not be secured, but from a visual examination there was certainly no doubt that superphosphate was extremely beneficial to the oat crop, especially in the matter of hastening maturity. No amount of superphosphate was able to promote root growth to the extent that the effects of severe nematode infestation could be overcome; there was no indication that superphosphate had any effect upon the nematode population, the most heavily infested spot in the field, and the one in which leaf symptoms first appeared, had received 1500 lbs. of superphosphate per acre.

It had been previously found that the tissues of diseased plants were notably deficient in phosphorous, using the method of Spurway (*13*). In unfertilized fields diseased plants had from 0–½ p.p.m. and it was thought that the leaf symptoms might in some way be connected with this deficiency. Accordingly, tissue tests were made on plants grown in the fertilized plots. The amount of available phosphorus supplied was reflected in the tissue tests. Healthy control plants gave a test of ½–1 p.p.m. while diseased control plants had only a trace. On the other hand diseased plants which had received small amounts of superphosphate contained from 2–2½ p.p.m. and those in the heavily fertilized plots had from 2½–5 p.p.m. The plants were able to absorb available phosphorous from the soil in spite of the infestation of nematodes in the roots.

The available evidence does not indicate that the foliage symptoms are due to a lack of essential mineral nutrients. It does suggest, however, that the major factor in the development of the diseased condition is an inability to secure adequate amounts of water. The appearance of the plants and the special severity of the disease during periods of drought are facts supporting this hypothesis.

DISCUSSION OF CONTROL MEASURES

Direct control methods do not seem to be practicable although numerous investigators have for years pursued this line of research. True, certain substances such as carbon disulphide and calcium cyanide will effect a control if applied in large quantities but the cost is prohibitive. Goffart (*5*) estimated that it would cost approximately $1,500.00 per acre to rid the soil of nematodes by means of calcium cyanide. Guba (*7*) used carbon disulphide emulsion against *Heterodera marioni* and on the basis of his figures it would cost about $485 per acre. A great many other chemicals have been used against various soil borne pathogens, among them are acetic acid, sulphuric acid, pyroligneous acid, cresylic acid, sulphur and formalin. The use of acid substances on a highly alkaline soil such as that found in the area is apparently of no avail; the heavy texture of the soil also makes it difficult to secure proper distribution of the materials in the soil. While admittedly it is not economically possible to treat large areas, the subject is worthy of further study. If some efficaceous treatment could be devised, it would be applicable in the case of a newly invaded small patch and thus avoid the infestation of a whole field.

The use of trap crops was devised in Germany against the sugar beet nematode many years ago. The method consisted in sowing an early

crop of rape or some other susceptible crop which was plowed up in a few weeks. Though some measure of control was obtained, it has not always been successful. The plowing up of infested oat fields early in June is probably good practice, not only to get rid of the weeds, but to expose the roots containing the immature larvae to the heat of the sun. Since there is apparently only one generation of nematodes during the growing season of the oat crop, this procedure might be of value in their control if done early enough. It is too late to plant oats or barley again but buckwheat may be planted or the fallow may be worked up during the summer.

Indirect control measures are proabaly more practicable and many different treatments are mentioned. Davidson (*2*) recommends early sowing, cultivation, land packing and the application of superphosphate to promote root development. Goodey (*6*) mentions the use of nitrogenous manures. Goffart (*5*) advocates shallow plowing and the use of plenty of seed to lessen the danger of attack, and warns that nitrogenous substances such as stable manure may also stimulate the parasite. Our own observations seem to indicate that the supplying of adequate available soil nutrients is not sufficient to enable the plant to overcome the attack. On the other hand, plants growing in soil tanks having adequate moisture, deep sown plants, and those growing in the packed soil of tractor wheel marks were all stimulated because of extra available moisture.

On the whole, the most promising methods of control seem to be crop rotation and the development of resistant varieties. So far no one has found any variety of oats which is resistant, but Nilsson-Ehle (*11*) reports that some varieties of barley are more resistant than others. Crop rotations of course, depend upon the host range of the parasite and upon the length of time it can persist in the absence of suitable hosts. The race which is present in Ontario is apparently found only on members of the Gramineae. As to the length of time the nematodes will remain in the soil, Fuchs (*3*) and Thorne (*14*) report that the cysts contain viable eggs for five to six years. Our own observations have shown that an interval of four years was sufficient to produce a healthy oat crop, but there were still a few larvae found to be present in the roots of some of the plants. We have not found nematodes below plow depth and that is undoubtedly the reason that severe winter frosts are able to affect them. The practice of shallow plowing and ridging the soil should exert a beneficial effect by allowing the frost to penetrate more thoroughly.

The problem of control is an individual one with each farmer concerned, depending upon whether he has to deal with only one infested field or his whole farm. If it is only a small patch or a single field, it should be seeded down to alfalfa and left for at least five years. However, few farmers can afford to do this with their whole farm, nor is it possible for us to issue blanket recommendations as to the best rotation to follow, since the need varies with the plan of farming being followed. The rotation should be five years or more in length on an infested farm; the acreage of spring grains msut be sharply curtailed and other crops such as roots, corn, beans, soy beans, clover and alfalfa should be substituted. Buckwheat is found useful in many cases. Field peas cannot be recommended in the district because of the destructive attacks of root-rotting fungi. The growing of winter wheat should be limited as it serves to propagate

the parasite, though not itself seriously affected. Finally, every effort should be made to get rid of wild oats in order that the nematodes may not be able to complete their development while non-susceptible crops are being grown.

CONCLUSIONS

The presence of the oat race of *Heterodera schachtii* in Ontario is to be regarded as a distinct menace to the growing of cereals over large areas in Ontario though, fortunately, the correlation of the infestation with one type of soil may be a factor in inhibiting its spread Farmers and agricultural workers should be on the lookout for new cases of infestation and every necessary assistance should be rendered to farmers in infested areas in their efforts to stamp out the parasite.

Although the place and date of the first infestation cannot be determined, the parasite is clearly an introduction. Since it now occurs over an area of at least thirty square miles, it must have been present for a considerable numer of years, even before certain farms began to experience consistent crop failures about ten years ago.

That *Heterodera schachtii* is to be regarded as the major causal factor of the "seedling disease" and subsequent crop failure, is pretty well established by the following observations. All the plants found to exhibit any foliage symptoms of the seedling disease were found to have also stunted and distorted root systems. In these poor root systems are to be found nematode larvae and sometimes various root rotting fungi. There was, however, no consistent association of any one fungus pathogen, and more over, in the early stages it was usual to find the distorted roots containing nematodes with no fungi present. The same fungi were isolated from lesioned roots not typically distorted, while in no case were distorted roots found without nematodes. The description of the disease, though differing in slight details, is similar to that described by European and Australian workers, and, together with the identification of the nematode, there is sufficient evidence to warrant the conclusion that we are dealing with a disease of cereals caused by the presence of the nematode *Heterodera schachtii*.

The presence of root-rotting fungi, especially in the later stages of the disease, must not be minimized or overlooked, for the nematode has apparently completed its work about halfway through the growing season. It is probable, therefore, that the true interpretation of a complete crop failure involves the influence of a number of secondary invaders coincident upon a root system already greatly disturbed by nematode infestation.

Summary

1. The presence of the oat race of the nematode *Heterodera schachtii* is reported for the first time in North America.

2. A description of the symptoms and effects of infestation upon the oat and barley crops is given, based upon two years' observation in the field.

3. A preliminary account of the life history of *Heterodera schachtii* under Ontario conditions is presented together with certain observations upon the spread and persistence of the organism in the soil.

4. A complete survey has been made of the infested district and a map prepared showing a correlation between nematode infestation and type of soil.

5. The chief methods of control together with their underlying principles are discussed, and their probable effectiveness is indicated from experiment and observation in the field.

ACKNOWLEDGMENTS

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LITERATURE CITED

1. Brown, H. D. The sugar beet nematode *Heterodera schachtii*—A new parasite in Canada. Sci. Agr. *12* : 544-552. 1932.

2. Davidson, J. Eelworms (*Heterodera schachtii* Schm.) affecting cereals in South Australia. Jour. of the Dept. of Agr. for South Australia, *34* : 378-385. 1930.

3. Fuchs, O. Beiträge zur Biologie der Rubennematoden *Heterodera schachtii*. Ziet. landw. Vchsw. Oest. *14* : 923-949. 1911.

4. Goffart, H. Versuche zur Bekämfung der Rübennematoden (*Heterodera schachtii* Schm.) mit Calciumcyanid. Arb. Biol. Reichsanst. Land-u. Forstw. *15* : 249-259. 1927.

5. Goffart, H. Untersuchungen am Hafernematoden *Heterodera schachtii* Schm. unter besonderer Berücksichtigung der schleswigholsteinischen Verhaltnisse I. Arb. Biol. Reichsanst. Land-u. Forstw. *20* : 1-26. 1932.

6. Goodey, T. Plant parasitic nematodes and the diseases they cause. xx + 306 pp. Methuen and Co., Ltd., London. 1933.

7. Guba, E. F. Carbon disulphide emulsion for the control of the root-knot nematode. Mass. Agr. Exp. Sta. Bull. 292 · 1-16. 1932.

8. Hickenbotham, A. R. Eeelworm, and No-growth patches. Jour. of the Dept. of Agr. of South Australia, *34* : 386-392. 1930.

9. Imperial Bureau of Agricultural Parasitology. The root infesting eelworms of the genus *Heterodera*. A bibliography and host list. viii + 99 pp. 1931.

10. Kühn, J. Ueber das Vorkommen von Rübennematoden an den Wurzeln der Halmfrüchte. Zeit. Ver. Rubenzucker. Ind. Zollver. *24* : 149-153. 1874.

11. Nilsson-Ehle, H. Ueber Resistenz gegen *H. schachtii* bei gewissen Gerstensorten, ihre Vererbungsweise und Bedentung für die Praxis. Hereditas I : 1-34. 1920.

12. Russell, R. C. A nematode discovered on wheat in Saskatchewan. Sci. Agr. *7* : 385-386. 1927.

13. Spurway, C. H. Soil Testing. A practical system of soil diagnosis. Michigan State College A.E.S. Technical Bulletin No. 132. 1933.

14. Thorne, G. Length of the dormancy period of the sugar beet nematode in Utah. Dept. Cir. United States Department of Agriculture. 262 : 1-5. 1923.

15. THORNE, G. *Heterodera punctata* n. sp. A nematode parasite on wheat roots from Saskatchewan. Sci. Agr. *8* : 707-711. 1928.

16. VANTERPOOL, T. C. *Asterocystis radicis* in the roots of cereals in Saskatchewan. Phytopathology *20* : 677-680. 1930.

17. VOIGT, W. Beitrag zur Naturgeschichte des Rüben-Hafer-und Erbsen-Nematoden (*Heterodera schachtii*). Deutsch landw. Pr. *19* · 813-815. 1892.

Résumé

Maladies des plantules d'avoine dans l'Ontario. 1. Le nématode de l'avoine Heterodera Schachtii Schm. D. F. Putnam et L. J. Chapman, Institut des recherches de l'Ontario, Toronto, Ont.

La présence du nématode *Heterodera schachtii* de la racine de l'avoine est signalée pour la première fois dans l'Amérique du Nord. Il est donné une description des symptômes et des effets de la présence de ce parasite sur les avoines et les orges, basée sur deux années d'observations dans le champ, ainsi qu'un compte-rendu préliminaire du cycle évolutif du *Heterodera schachtii*, dans les conditions de l'Ontario, et certaines observations sur la propagation et la persistance de l'organisme dans le sol. Une inspection complète du district infesté a été faite et une carte a été préparée, montrant la corrélation entre l'invasion de nématodes et le type de sols. Les principaux moyens de lutte ainsi que les principes sur lesquels ils s'appuient sont discutés, de même que leurs effets probables, basés sur les expériences et les observations faites dans le champ.

THE GROWTH OF TURNIPS IN ARTIFICIAL CULTURES[1]

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During the last ten years a wide range of nutritional studies has been made by this laboratory with various horticultural crop plants, employing the sand-culture method. At an early stage it was recognized that lack or deficiency of minor elements such as boron and manganese might confuse or upset the results secured from known variants, so that minute amounts of these two elements have been employed in the basic culture solution (*2*). Knowledge of safe concentrations of these two elements in the culture solution for the plants studied was secured from the literature, but no results had been obtained by the authors concerning optimum concentrations, toxic concentrations, or the symptomatic effects brought about by deficiencies or excesses. As a preliminary to mineral nitrogen studies with the turnip it was considered advisable to first test the suitability of the basic culture solution for growing turnips and at the same time gain symptomatic information regarding the effect of deficiency or excess of the element boron as well as its effect on the intake and utilization of other mineral elements.

Warington (*6*) showed that broad beans attained full development only when a trace of boron was given. The best results were obtained with quantities of the order of one part of H_3BO_3 per million of the culture solution; amounts greater than 1 in 5,000 were harmful. Sommer and Sorokin (*5*) studied the effect of the absence of boron on the growth and development of *Pisum sativum* in culture solutions. They found that the meristematic region of root tips grown without boron becomes abnormal. The cells cease dividing normally and existing cells undergo premature development or pathological changes; in a general way the absence of boron causes a disturbance in the regulation of growth and development. Johnston and Dore (*3*) found that the element boron in a concentration of approximately 0.5 ppm. was necessary for the normal growth and development of the tomato. In the absence of this element four distinct types of injury occurred; death of the terminal growing point of stem; breaking down of the conducting tissues in the stem; characteristic brittleness of stem and petiole; and roots of extremely poor growth and of a brownish unhealthy colour. A concentration of 5.5 ppm. boron in the nutrient solution was toxic to tomato plants.

McHargue and Calfee (*4*) report that boron is essential for the growth of lettuce and that when it is excluded from the nutrient solution, a severe deficiency disease results which is characterized by malformation of the more rapidly growing leaves, spotting and browning of the leaf tips, and death of the growing point of the plant. The optimum concentration of boron was found to be 0.7 ppm. while concentrations from 1.2 to 2.5 ppm. produced increasing toxicity.

Brandenburg (*1*) working with sugar beets in sand found that as high as 30 mg. boric acid could be added to a ten litre pot without causing

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any signs of toxicity due to excess boron and that even this application gave very weak symptoms of boron deficiency after a prolonged period of growth. Weight and per cent sugar content were directly proportional to the boron supply. Analysis showed lower boron content in diseased than in healthy plants with a remarkably high ash content in diseased beets.

MATERIALS AND METHODS

Two varieties of turnips were employed: Canadian Gem, a Swede grown to a considerable extent for table use; and Ditmar Swede, a field variety. Seeds were germinated in greenhouse soil and pricked out into two-inch pots in soil where they were held for a short time. The soil was then washed off the roots and the plants transferred to washed sandstone in four-inch clay pots the walls of which had been coated with wax. After the plants had made sufficient root growth, they were transferred to glazed stone jars of three gallon capacity containing sand-stone. Bakers c.p. chemicals were used throughout for the making up of culture solutions. No attempt was made to repurify the c.p. chemicals used in this experiment; the failure of plants to develop in solutions made with them but without the addition of boron indicated this was unnecessary. Due to the fact that the plants were started in soil and the chemical salts not repurified the appearance of boron deficient symptoms were probably delayed but since turnips have a relatively large capacity for the element boron the purpose of the experiment was not defeated.

The deficient boron nutrient solution employed as a basic formula for all plants is given below.

Stock nutrient solutions

$MgSO_4, 7H_2O$	140 gms. in 2,000 cc. water.
$KH_2\ PO_4$	70 gms. in 2,000 cc. water.
$Ca\ Cl_2$	150 gms. in 2,000 cc. water.
$NH_4\ NO_3$	360 gms. in 4,000 cc. water.
$MnSO_4 . 2H_2O$	1 gm. in 2,000 cc. water.
$K\ NO_3$	50 gms. in 2,000 cc. water.

From these stock solutions the nutrient solution was made up as follows:

Amount of stock solution in 2,000 cc. water.

$MgSO_4, 7H_2O$	28 cc.
$KH_2\ PO_4$	31 cc.
$Ca\ Cl_2$	29 cc.
KNO_3	80 cc.
$NH_4\ NO_3$	81 cc.
$MnSO_4 . 2H_2O$	2.1 cc.
$FeCl_3$	10 cc. of 0.5% solution.

Five different boron treatments were employed, each treatment consisting of five plants. Boron was supplied in the form of boric acid.

I. Boron to be deficient.
II. Boron concentration of solution 0.25 ppm.
III. Boron concentration of solution 0.5 ppm.
IV. Boron concentration of solution 1 0 ppm.
V. Boron concentration of solution 1.5 ppm.

Parts per million of the elements in the nutrient solution

Series	N	P	K	Mg.	Ca.	S	Mn.	B	Fe.
1	1878	122.8	930	96 4	400	127	0.19	000	3 44
2	1878	122 8	930	96.4	400	127	0 19	0 25	3 44
3	1878	122 8	930	96 4	400	127	0.19	0 50	3 44
4	1878	122 8	930	96 4	400	127	0 19	1.00	3 44
5	1878	122.8	930	96 4	400	127	0 19	1 50	3.44

Solutions were fed once a week at the rate of 200 cc. per pot. During the growth of the plants each pot received eighteen applications of nutrient solution so that the total amount of boric acid fed per pot is as follows:

Series		Series	
1	0	4	20 16 mg.
2	5 04 mg.	5	30 24 mg.
3	10 08 mg		

RESULTS

Growth Characteristics

After being subjected to these treatments for a period of six weeks, series No. 1 receiving no boron showed definite signs of boron deficiency. The injury commenced as a light yellow marginal colouring of the leaves in time involving large areas (Figure 1) The region next to the veins remained green the longest. In some cases the under sides of the leaves were markedly reddish-purple. At this time the only other treatment exhibiting deficiency symptoms was series 2 which showed slight marginal yellowing on a few of the bottom leaves. After a period of ten weeks two of the plants in series 1 were completely dead with the other plants stunted,

FIGURE 1. Leaf from plant receiving 1 5 ppm. boron—normal appearance. Right.—Leaf from plant lacking boron. Showing marginal yellowing in the initial stages of boron deficiency.

yellowing of the leaf margins, leaves curled, white scorched, shrivelled, dying from the margin and growing point (see Figures 2 and 3). Leaf petioles had dried up, corky growth on both inner edges sometimes advancing into the midrib. The roots were small and shrivelled or rotting at their juncture with the top. In series 2 receiving 0 25 ppm. of boron, the plants had made fairly good growth although many of the leaves were noticeably curled, and yellowed at the margins with distinct purple pigmentation. A considerable proportion of the leaves were dying. Roots were medium in size (see Figure 4.) Plants receiving 0 5 ppm. of boron were considerably more vigorous, and larger in size with better foliage than the previous two treatments. However, foliage injury still persiste l of the same character but reduced in severity. Roots were large in size. Plants receiving 1 and 1 5 ppm. of boron were large and vigorous with very large roots. A very small amount of foliage injury still persisted There was a gradual increase in vigour, size of roots and decrease of foliage injury as the concentration of boron in the nutrient solution was increased, until in plants receiving 1 0 and 1 5 parts per million plants were almost normally healthy in appearance (see Figure 3).

FIGURE 2. Plant grown with boron lacking solution.

FIGURE 3. Left.—Boron concentration 1 ppm. Centre.— 25 ppm boron. Right.-Lacking boron.

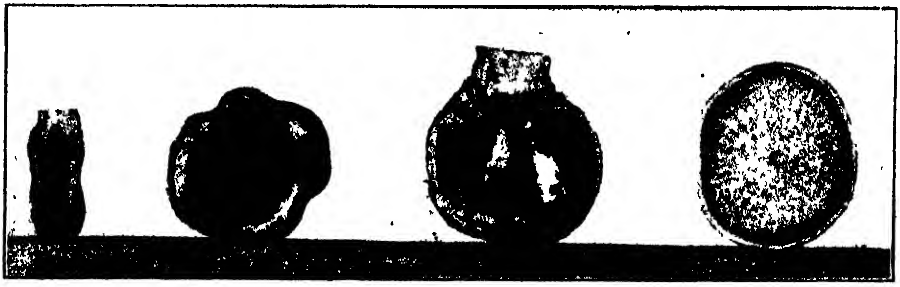
0 ppm. .25 ppm. .50 ppm. 1 0 ppm. 1.5 ppm.

Figure 4. Showing root development under the range of boron concentrations employed.

Boron treatment	Canadian Gem		Ditmar Swede	
	Average root diameter in inches	Average weight in ounces	Average root diameter in inches	Average weight in ounces
Deficient	0 6 (2 dead)	2 0	1 8	5 5
0 25 ppm.	3 2	16 2	3 7	30 0
0 50 ppm.	4 1	32 0	4 4	31 0
1 00 ppm.	3 8	35 4	4 5	44 8
1 50 ppm.	4 1	29 0	4 56	50 7

Root Formation and Characteristics

Root formation in plants receiving deficient boron nutrient solution was practically absent. Two of the five plants in the variety Canadian Gem and three plants in the variety Ditmar Swede rotted off at the junction of top and root and the small root already formed, decayed. Plants that survived formed but very small roots which were affected with hollow heart (see Figures 4 and 5). When 0.25 ppm. of boron were supplied in the nutrient solution plants were able to form roots of fairly good size though still considerably smaller than those procured when the boron



0 ppm. .25 ppm. 50 ppm. 1 5 ppm.

FIGURE 5. Showing cross-section of roots produced under the different boron concentrations. One root from series receiving 1 5 ppm of boron entirely free from disorder.

concentration was increased. However, when the roots from this treatment were cut open they were all found to be seriously affected with hollow heart. In the variety Canadian Gem, four of the five roots were severely affected with hollow heart, while in the variety Ditmar Swede, three of the roots were hollow hearted.

The next highest concentration of boron, 0 5 ppm., produced roots still considerably greater in size. In both varieties four of the roots were severely affected with hollow heart while the fifth root in the case of the variety Ditmar Swede, had a narrow zone of sound flesh around the perimeter of the root.

In series 4 receiving 1 ppm. of boron hollow heart was entirely absent. Although every root showed some sign of the trouble, the area affected was reduced. In both varieties, two roots had a narrow zone of sound flesh around the perimeter with the other three roots having the upper half of the flesh healthy.

In the highest concentration of boron employed, there was a still further reduction in the severity of the trouble. One root in each variety was entirely free from any sign of disorder while in the other roots the affected flesh was confined to a small area at the centre or at the base.

TABLE 1.—ASH ANALYSES WERE MADE OF THE LEAVES AND THE ROOTS, THE RESULTS OF WHICH ARE TABULATED BELOW

Treatment	% Dry matter	Carbonate ash as % Dry matter	Ash constituents as % Dry matter							
			SiO_2	Fe_2O_3	Al_2O_3	Mn_3O_4	K_2O	CaO	MgO	P_2O_5
Canadian Gem Leaves										
0 25 ppm. boron	8 29	8 37	0 17	0 06	0 06	0 005	1 85	1 64	0 61	1 11
1 5 ppm boron	10 14	7 62	0 22	0 07	0 01	0 01	1 64	1 81	0 62	1.00
Ditmar Swede Leaves										
0 25 ppm. boron	9 55	8 14	0 30	0 09	—	0 01	2 32	1 62	0 54	1.07
1 5 ppm boron	10 29	7 40	0 31	0 05	0 03	0 003	2 04	1 42	0 58	1 21
Canadian Gem Roots										
0.25 ppm. boron	14 34	7 34	0 42	0 05	0 61	0 002	2 77	0 90	0 38	0 60
1 5 ppm. boron	13 78	4 57	0 11	0 01	0 02	Trace	1 85	0 56	0 21	0.29
Ditmar Swede Roots										
0 25 ppm. boron	10 31	8 96	0 17	0 01	0 03	0 003	3 70	0 98	0 49	0 85
1 5 ppm. boron	13 41	5 45	0 05	0 02	0 02	Trace	2 21	0 72	0 35	0 51

One of the most outstanding features of the analytical data is the very low ash in dry matter of the high boron roots as compared with the low boron roots. These results are similar to those reported by Brandenburg (*1*) in his work with sugar beets.

There is a possible greater concentration ot potassium in the leaves when the boron supply is low with a pronounced increase of potassium in the roots when boron is low in both varieties. Analyses of the leaves from the two varieties gives contradictory results for calcium but in the roots a decided reduction of calcium accumulation where boron is fed. Warington (*7*) suggests that some kind of relationship exists between boron and calcium, the exact nature of which is yet undetermined. There does

not appear to be any relationship between the boron supply and the magnesium content of the leaves but where boron is deficient a decided accumulation of magnesium appears evident in the roots. There is also a decided increase in phosphorus accumulation in the low boron roots as compared with those receiving a greater supply. Deficiency of boron causes an accumulation of potassium, phosphorus, magnesium and calcium in the roots.

Boron determinations were made on the roots from these treatments the results of which are tabulated below. These boron figures were supplied through the courtesy of the Chemistry Division, Central Experimental Farm.

Identity—Treatment	Boron as B_2O_3 in ash
Ditmar Swede no boron solution	.005%
Ditmar Swede 0.5 ppm. boron solution	.015%
Ditmar Swede 1.0 ppm. boron solution	.025%
Ditmar Swede 1.5 ppm. boron solution	.035%
Canadian Gem 0.5 ppm. boron solution	.015%
Canadian Gem 1.0 ppm. boron solution	.025%

There is a direct relationship between the amount of boron provided in the nutrient solution and the amount of boron found in the roots. There exists an inverse relationship between the amount of boron found in the roots and the severity of hollow heart. In addition to the close relationship exhibited between the amount of boron fed and the decrease of hollow heart present it is of interest to note that very satisfactory turnips have been grown by the use of culture solutions. In fact, the higher boron concentrations produced turnips quite comparable in size and quality with those produced in the field.

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Acknowledgments are made to Mr. M. B. Davis, Dominion Horticulturist, at whose suggestion this work was conducted, and whose direction and assistance is much appreciated.

SUMMARY

Employing pot sand cultures boron deficiency was characterized by a marginal yellowing of the foliage followed by a purpling and scorching. Roots were small and shrivelled or rotted at their juncture with the top. Supplying 0.25, 0.50, 1.0 and 1.50 ppm. of boron in the culture solution caused a progressive decrease of foliage injury. An inverse relationship was found between the amount of boron supplied and the occurrence of hollow heart of the roots. An inverse relationship was found between the amount of boron fed and the percentage ash in dry matter of the roots. A direct relationship was found between the amount of boron fed and the amount of boron found in the roots.

REFERENCES

1. BRANDENBURG, E. Die Herz und Trockenfaule der Rüben Ursacheund Bekämpfung. "Angewandte Botanik" *14* : 194-228 1932.

2. HILL, H., DAVIS, M. B., and JOHNSTON, F. B. Nutritional Studies with Chrysanthemums. Sci Agri. *15* 110-125 1934.

3. JOHNSTON, EARL S and W. H. DORE The influence of boron on the chemical composition and growth of the tomato plant. Plant Phys. *4* 31-62 1929.

4. McHARGUE, J S and R K CALFEE Further evidence that boron is essential for the growth of lettuce Plant Phys *8* 305-313. 1933

5. SOMMER, A L. and HELEN SOROKIN Effects of the absence of boron and of some other essential elements on the cell and tissue structure of the root tips of Pisum sativum. Plant Phys *3* . 237-54 1928

6. WARINGTON, K The effect of boric acid and borax on the broad bean and certain other plants Ann Bot *37* . 629-72 1923

7. WARINGTON, K Studies in the absorption of calcium from nutrient solutions with special reference to the presence or absence of boron. Ann. Bot. *48* . 743-776. 1934

Résumé

POUSSSE DES NAVETS DANS DES CULTURES ARTIFICIELLES. H. Hill et E. P. Grant, Ferms expérimentale centrale, Ottawa, Ont.

Lorsque la culture de navets était faite en pots, dans du sable, le manque de bore se manifestait par un jaunissement marginal du feuillage qui prenait ensuite une apparence violette et brûlée Les racines étaient petites, racornies ou pourries à leur jonction avec la tige Un apport de 0 25, 0 50, 1 0 et 1 50 ppm. de bore dans la solution de culture a causé une diminution progressive du désordre On a constaté qu'il y avait une relation inverse entre la quantité de bore fournie et la présence du cœur creux des racines, de même qu'entre la quantité de bore fournie et le pourcentage de manière minérale dans la matière sèche des racines. Par contre, il y avait relation directe entre la quantité de bore fournie et la quantité de bore trouvée dans les racines

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

Wholesale prices in Canada were fractionally higher in March, the index being 72.0 compared with 71.9 in February. There were slight gains in the indexes of vegetable products, of animals and their products, iron and its products, non-metallic minerals and their products, and non-ferrous metals and their products. The most marked recession took place in the fibres, textiles and textile products group. Retail prices were slightly lower, the index being 79.0 compared with 79.1 in February. The index of retail prices of food advanced from 69.2 to 69.5. However, the clothing index fell from 71.3 to 70.3. The index of the value of retail sales advanced from 59.1 in February to 68.2 in March. This gain was not as large as that in the corresponding months of 1934 but this may be accounted for in the fact that Easter sales took place in March last year.

Employment.—The seasonally adjusted index of employment was 98.9 at April 1st, compared with 101.3 at March 1st. The index for manufacturing advanced from 94.4 to 95.1. Employment in mineral production was also slightly higher as was the case in logging.

Physical Volume of Business.—Following substantial gains in January and February the index of the physical volume of business dropped to 94.2 in March. Industrial production fell from 101.1 in February to 93.3. Mineral production showed a fractional decrease. Manufacturing, however, experienced a rather sharp decline from 92.5 to 86.8. Most of the sub-indexes in this group appear to have fallen. Food stuffs declined from 75.9 to 72.5, tobacco from 143.7 to 122.8, and iron and steel production from 92.3 to 90.2. The forestry index was lower but automobile construction was slightly higher than in February. The index of construction registered a decline of from 76.9 to 51.3. Marketings of grain and live stock were higher than in February and cold storage holdings in March were slightly above those of the first of February.

Agricultural Products.—The index of wholesale prices of Canadian farm products has been rising steadily since October, 1934, being 62.7 for March. The index for field products was 56.4 in March compared with 55.7 in February. The average price of No. 1 Northern wheat, cash basis at Fort William and Port Arthur in March, was 81.9 cents as compared with 79.5 in February, 1935, and 66.4 in March, 1934. Prices of other grains were slightly lower than in the previous month. The index of prices of animals and their products advanced from 72.6 in February to 73.3 in March. Average prices for the better grades of all classes of live stock were higher but those of lower grades showed some recession because of larger supplies.

Marketings of grain during the month of March were higher than in the previous month. The total index rose from 55.2 to 57.7, larger shipments of wheat and rye more than offsetting declines in the movement of oats, barley and flax.

The index of live stock marketings rose from 93.4 to 100.0 or the equivalent of the monthly average for 1926. The movement of cattle, calves, and sheep was well above the average but there was a slight recession in hog marketings at inspected plants. Cold storage holdings as already indicated were slightly higher at the beginning of March than at the first of February, increased stocks of butter and mutton being responsible for the higher index.

Conditions in United States.—A moderate increase in acreage of principal farm crops is indicated in reports to the United States Department of Agriculture with about the usual plantings of potatoes, oats, barley, and rye. The total spring wheat acreage planted in 1934 was 9,290,000 acreas whereas intentions this year are estimated at 17,847,000. Other crop acreages are: oats, 39,108,000 compared with

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1934	71.6	59.0	53.9	67.6	78.9	94.2	93.6	88.5	114.2
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.8
Nov.	71.2	61.2	55.7	70.4	79.4	96.5	97.0	51.2	130.4
Dec.	71.2	61.6	56.0	70.9	79.0	92.4	91.0	36.0	135.7
1935									
Jan.	71.5	61.4	55.7	71.0	78.9	97.5	97.8	30.6	143.7
Feb.	71.9	62.0	55.7	72.6	79.1	100.6	101.1	62.2	141.2
Mar.	72.0	62.7	56.4	73.3	79.0	94.2	93.3	65.4	143.2

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1933, p. 15.

2. Wholesale prices of Canadian products of farm origin only See Prices and Price Indexes 1913-1933, p. 33, and Monthly Mimeographs 1934 and 1935.

3 Wholesale prices of grains, fruits and vegetables

4. Wholesale prices of Animals and Animal Products

5. Including foods, rents, fuel, clothing and sundries. See Prices and price Indexes 1913-1928, pp. 181-185, 290-293 1926 = 100

Prices and Price Indexes 1913-1931, p. 108, and Monthly Mimeographs 1934-1935.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

30,395,000 last year, barley, 11,954,000 compared with 7,144,000; potatoes, 3,272,000 compared with 3,303,000; tame hay, 53,117,000, compared with 51,495,000, and tobacco 1,511,000 against 1,335,000 in 1934. Indexes of prices of farm products for March show that those of cotton, fruits, truck crops, dairy products, chickens and eggs declined, while those of meat animals advanced. The total index was 108

compared with 111 in February. The index of prices paid by farmers for commodities bought was 128 compared with 127, and the ratio of prices received to prices paid fell from 87 in February to 84 in March. These indexes are based on the average 1910–14.

Urban conditions are somewhat variable. The index of industrial wages in New York State factories was 189 in February compared with 188 in January and 180 in November, 1934. The index of factory employment was 81 9 in March of this year, compared with 81 0 in March, 1934, and the highest point reached since May of last year. Manufacturing production was slightly higher in March this year, the index being 88 compared with 82 0 in March of last year. Mineral production was 95 0 and 100 0 respectively whereas industrial production was 89 compared with 84. The Bureau of Labour index number of wholesale prices was 116 in February representing a gain of 9 points over that for February, 1934. This index was 115 in January, 1935, but throughout 1934 never rose above 113, which point was reached in September.

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE, OTTAWA, PRINCIPALEMENT D'APRÈS LES DONNÉES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

Les prix du gros au Canada ont remonté d'une fraction en mars; l'indice était à 72·0 contre 71·9 en février. L'indice des produits végétaux, des animaux et de leurs produits, du fer et de ses produits, des minéraux non métalliques et de leurs produits et des métaux non ferreux et de leurs produits s'est un peu relevé. C'est dans le groupe des fibres et des matières textiles que la plus forte régression a été enregistrée. Les prix du détail ont légèrement baissé, l'indice étant à 79·0 contre 79·1 en février. L'indice des prix du détail de la nourriture est monté de 69·2 à 69·5, mais l'indice des vêtements est tombé de 71·3 à 70·3. L'indice de la valeur des ventes au détail, qui était à 59·1 en février, est monté à 68·2 en mars. Ce gain n'est pas aussi fort que pendant les mois correspondants de 1934, peut-être parce que les ventes de Pâques ont eu lieu en mars l'année dernière.

Emploi. L'indice de l'emploi ajusté pour la saison était à 98 9 au 1er avril contre 101·3 au 1er mars. L'indice pour les manufactures est monté de 94 4 à 95·1. L'emploi dans la production minérale était aussi un peu plus élevé, de même que dans l'industrie du flottage des bois.

Volume physique des affaires.— Après avoir enregistré un gain considérable en janvier et février, l'indice du volume physique des affaires est tombé à 94·2 en mars. La production industrielle, de 101·1 en février, est tombée à 93·3. La production minérale accusait également une baisse fractionnelle. L'industrie manufacturière a subi une assez forte régression; l'indice est tombé de 92·5 à 86·8. La plupart des sous-indices dans ce groupe paraissent avoir reculé. Les denrées alimentaires sont tombées de 75·9 à 72·5, le tabac de 193·7 à 122·8 et la production du fer et de l'acier de 92·3 à 90·2. L'indice des forêts était plus faible, mais la construction des automobiles un peu plus élevée qu'en février. L'indice du bâtiment a enregistré une baisse de 76·9 à 51·3. Les ventes de grains et de bestiaux sur pied étaient plus élevées qu'en février, et les stocks entreposés au froid en mars un peu supérieurs à ceux du 1er février.

Produits agricoles.—L'indice des prix de gros des produits de ferme canadiens n'a cessé de s'élever depuis octobre 1934; il était à 62 7 en mars. L'indice des produits des champs, qui était de 55·7 en février, s'est élevé à 56·4 en mars. En mars, le prix moyen du blé Nord N° 1, base comptant, à Fort William et Port Arthur, était de 81·9 cents, contre 79·5 en février 1935 et 66 4 en mars 1934. Les prix des autres grains étaient un peu plus bas que le mois précédent. L'indice des prix des animaux et de leurs produits est passé de 72·6 en février à 73·3 en mars. Les prix moyens pour les meilleures catégories de toutes les espèces de bestiaux étaient plus élevés, mais ceux des catégories inférieures ont un peu diminué à cause de l'offre plus abondante.

En mars, les ventes de grain ont été plus fortes qu'au cours du mois précédent. L'indice total s'est élevé de 55·2 à 57·7; les expéditions plus fortes de blé et de seigle ont largement couvert la diminution dans les expéditions d'avoine, d'orge et de lin.

L'indice des ventes de bestiaux s'est élevé de 93·4 à 100·0, soit l'équivalent de la moyenne mensuelle pour 1926. Le mouvement des bovins adultes, des veaux et des moutons était bien supérieur à la moyenne, mais il y a eu une légère diminution dans les ventes de porcs aux salaisons inspectées. Comme nous le disions plus haut, les stocks entreposés au froid étaient un peu plus considérables au commencement de mars qu'au 1er février; cette augmentation portait surtout sur les stocks de beurre et de viande de mouton.

Conditions aux Etats-Unis.—Les rapports reçus par le Ministère de l'Agriculture des Etats-Unis signalent une augmentation modérée dans l'étendue des principales récoltes de la ferme; les plantations de pommes de terre, d'avoine, d'orge et de seigle

sont à peu près égales à l'ordinaire. En 1934, les emblavures totales de blé de printemps étaient de 9,290,000 acres, tandis que les prévisions pour cette année sont estimées à 17,847,000 acres. Les étendues des autres récoltes sont les suivantes: avoine, 39,108,000 acres, contre 30,395,000 l'année dernière; orge, 11,954,000 acres contre 7,144,000; pommes de terre, 3,272,000 acres contre 3,303,000; foin cultivé, 53,117,000 acres, contre 51,495,000; tabac, 1,511,000 acres, contre 1,335,000 en 1934. Les indices des prix des produits de la ferme en mars montrent que ceux du coton, des fruits, des légumes potagers, des produits laitiers, des poulets et des œufs ont baissé, tandis que ceux des animaux à viande ont monté. L'indice total était à 108, contre 111 en février. L'indice des prix payés par les cultivateurs pour les marchandises achetées était à 128 contre 127, et la relation entre les prix reçus et les prix payés est descendue de 87 en février à 84 en mars. Ces indices sont basés sur la moyenne de 1910-14.

Les conditions urbaines sont assez variables. En février, l'indice des salaires dans les fabriques de l'état de New York était à 189, contre 188 en janvier et 180 en novembre 1934. L'indice de l'emploi dans les fabriques était à 81·9 en mars de cette année, contre 81·0 en mars 1934; c'est le plus haut point depuis mai de l'année dernière. La production manufacturière était un peu plus élevée en mars cette année; l'indice était à 88 contre 82·0 en mars de l'année dernière. La production minérale était à 95 0 et 100 0, respectivement, tandis que la production industrielle était à 89 contre 84. L'indice des prix de gros du Bureau du Travail était à 116 en février, soit une augmentation de 9 points sur février 1934. Cet indice était à 115 en janvvier 1935, mais au cours de 1934 il n'a jamais dépassé 113, atteint en septembre.

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SOME FIELD AND LABORATORY STUDIES OF SOIL DRIFTING IN SASKATCHEWAN[1]

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The severe drought which Western Canada has experienced during recent years has intensified many of the problems incidental to agricultural practice in semi-arid regions; one of the most outstanding examples is that of wind-erosion or soil drifting, which has become a serious menace in many districts.

It is a known fact that soil drifting occurred during periods of drought in the early years of settlement in Manitoba and southeastern Saskatchewan. Since the breaking up of vast stretches of grass-land in western Saskatchewan and Alberta, the condition has become more widespread and severe whenever climatic factors have favored its occurrence. It is worthy of note that the problem of soil drifting was one of the important studies undertaken by the Royal Commission of Inquiry into Farming Conditions in Saskatchewan, 1921 (*7*). The problem has also been discussed in papers dealing with methods of control (*1*, *9*).

The Saskatchewan Soil Survey, which originated from a recommendation of the above commission, has published to date nine survey reports covering various areas of Saskatchewan (*2*) Reference is made in the reports to those soils found to be subject to drifting at the time the surveys were made. Briefly they were the very heavy soils such as heavy clays and clays and the very light soils such as sandy loams and sands. The medium textured soils were not subject to drifting, except those types of a distinctly silty nature, such as silt loams and silty clay loams.

Field Observations

The soil survey field work during the past summer involved a general traverse of the zones and the main soil groups with a view to completing the reconnaissance survey map of the province. In addition to the main project, it was decided to make observations of soil drifting in relation to soil types, and also to secure samples for laboratory studies. The objectives sought were a comparison of the present conditions of soil drifting with those found during the earlier surveys, and some data on the chemical and physical composition of undrifted cultivated soils and related drifted material.

[1]Contribution from the Department of Soils.

The classification of Saskatchewan soils into zones, series, and types has been described in several papers by Joel (*4*, *5*, *6*) and is also discussed in the provincial soil survey reports (*2*). It will be sufficient here to list the zones in succession. Beginning with the semi-arid region of south-western Saskatchewan, the main soil zones are: the semi-arid brown prairie; the semi-arid dark brown prairie; the sub-humid black park; and the sub-humid gray wooded. A sketch map showing the approximate location of the zones is given in Figure 1.

The soil series referred to in the following pages may be placed in four groups, each group consisting of soils having similar textural ranges and parent materials, but occurring in different zones. In each group the first named series occurs in the brown prairie zone, the second in the dark brown prairie zone, and the third in the black park zone. This series grouping is given below:

1. Sceptre, Regina and Indian Head Series. These are heavy textured soils derived from lacustrine deposits and Pierre shale.
2. Fox Valley, Elstow and Melfort Series. These include medium and heavy textured soils derived from silty lacustrine deposits.
3. Haverhill, Weyburn and Oxbow Series. These include medium and light textured soils derived from glacial till and morainic deposits.
4. Hatton, Asquith and Meota Series. These include light textured soils derived from pre-glacial sandstones and recent alluvial and aeolian deposits.

The relation of the above mentioned soil types to their tendency to drift is shown in Table 1. The soils are grouped according to the degree

TABLE 1—THE OBSERVED RELATION OF SOIL DRIFTING TO SOIL TYPE IN SASKATCHEWAN

Soil Zone	Soil Type		Observed Drifting
Brown Prairie	Sceptre	—heavy clay, clay	Severe
Brown Prairie	Fox Valley	—silty clay loam, silt loam	Severe
Brown Prairie	Haverhill*	—clay loam, loam, light loam	Severe
Brown Prairie	Haverhill	—sandy loams	Severe
Brown Prairie	Hatton	sandy loams	Severe
Brown Prairie		—sands	Severe
Dark Brown Prairie	Regina	heavy clay, clay	Severe
Dark Brown Prairie	Weyburn	—fine sandy loams	Severe
Dark Brown Prairie	Asquith	sandy loams	Severe
Dark Brown Prairie		—sands.	Severe
Dark Brown Prairie	Regina	—clay loam.	Moderate
Dark Brown Prairie	Elstow	—silty clay loam; silt loam.	Moderate
Dark Brown Prairie	Weyburn	—clay loam, loam, light loam.	Moderate
Dark Brown Prairie	Asquith	—light loam	Moderate
Black Park	Indian Head	—clay.	Severe
Black Park	Oxbow	—sandy loams.	Severe
Black Park		—sands.	Severe
Black Park	Melfort	—silty clay loam; silt loam.	Moderate
Black Park	Oxbow	—clay loam; loam; light loam.	Moderate
Black Park	Meota	—light loam; sandy loam.	Moderate

*Severe drifting of Haverhill clay loam and loam is of local occurrence and affects only a small part of the total area of these soils.

of severity of drifting observed in the field. It is not to be inferred that the soils grouped under severe drifting are always found in this state. The degree of drifting in the Sceptre series, for example, varies from severe to none, according to local conditions. This table is intended to indicate the soil types on which some serious drifting is occurring at the present time.

The data in Table 1 indicate that in general the severe drifting occurs on the heavy and light soils. In the case of the brown soil zone, severe drifting also occurs on the silty soils of the Fox Valley Series, and in certain localities, on the medium textured glacial soils of the Haverhill series. Earlier observations, discussed in Soils Survey Report No. 9 (*2*), indicated that the soils of the above mentioned series were not subject to serious drifting. This year's observation showed that wherever these soils were drifting badly there had been a succession of more or less complete crop failures. It is reasonable to assume therefore that the increased severity of drifting is due in part to the disappearance of stubble and crop residues, coupled with the effects of cultural practices In the dark brown zone, medium textured soils of the Elstow and Weyburn series, which are quite similar in general character to the Fox Valley and Haverhill soils, respectively, did not appear to be drifting so severely.

It is interesting to note that some drifting is occurring in the sub-humid park zone on soils that have a very high content of humus or decomposed organic matter. The opinion has been frequently expressed that one of the chief causes of drifting in southwestern Saskatchewan is the loss of humus as a result of prevailing agricultural practices. Such a soil as the Melfort silty clay loam, which is subject to drifting, contains far more humus than could be built up in the soils of the semi-arid brown soil zone.

Irrespective of zonal position a considerable amount of fresh drifting was observed in uncultivated fine sand and dune areas, probably the result of overgrazing or some other disturbance of the natural vegetation.

There are a number of soils not listed in the table which are very little subject to drifting. Among these may be mentioned the complexes of solonetz soils of the brown and dark-brown zones (including the so-called "burn-out" soils), and the medium textured podzolic and degraded soils of the park and wooded zones. Slight drifting has been noted on podzolic fine sandy loams and sands of the wooded zone

It is not possible to state definitely the relationship of topography to soil drifting. Most of the soils under discussion have gently undulating to gently rolling topographies. The topography of many of the medium and light soils is rougher than that of the clay and silty lacustrine soils. In the strong y rolling areas there appears to be a tendency for drifting to occur chiefly on knolls and ridges. This may be due to the relatively lighter texture of the soils in these positions and in part to their greater exposure to wind action compared to lower slopes. However, the strongly rolling and hilly lands under cultivation occupy but a smal part of the total cultivated area of the province.

While this paper is primarily concerned with wind erosion, it is worth while noting that in southern Saskatchewan water erosion has also been

observed. The latter type of soil erosion is occurring on lands having rough, hilly topography, and also on adjacent lands of more gentle slope and lower elevation. The areas affected are local in extent, but both gullying and sheet-erosion on a small scale are to be found on cultivated fields. It is possible that individual farms may suffer considerable damage from this form of soil erosion.

The serious effects of drifting are most clearly seen on the lighter soil types, particularly on the sandy loams and sands. The effects are shown by damage to crop growth and destructive changes in the original soil. Severe drifting exposes the sandy subsoil, while the drifted material accumulates in miniature sand dunes. As a result, many fields formerly under cultivation are now practically devoid of vegetation and have been abandoned.

In the case of the clay soils, the fertility of both the drift and the soil seems to be practically unimpaired, as is shown by the uniformly good growth of vegetation occurring on such lands when moisture conditions again become favorable. The drift appears to be quite as uniform in texture as the original soil.

The drifted material from medium textured glacial soils is of a distinctly sandy nature when compared with the original soil. However, in the case of medium silty types there is less textural difference between the drift and the soil. The increase in recent years of soil drifting on medium textured soils formerly regarded as fairly resistant to wind erosion is another factor which points to the seriousness of the problem at the present time.

Laboratory Studies

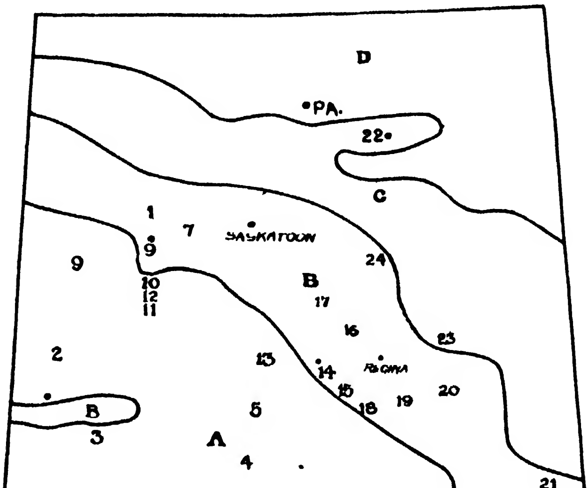

FIGURE 1.—Sketch map of southern Saskatchewan, showing main soil zones and approximate locations where soil and drift samples were taken. A, brown prairie zone; B, dark brown prairie zone; C, black park zone; D, gray wooded zone. The figures show locations of samples and also refer to the sample numbers as reported in Tables 2 and 3.

The samples taken for laboratory study were selected to represent the cultivated surface soil and the drifted material from the same soil type, taken in the same vicinity. The approximate locations of the samples are shown in Figure 1.

The following determinations were made: observations of texture, structure and colour; effervescence with dilute HCl; colorimetric pH; hygroscopic moisture at 105° C.; loss on ignition at 550-600° C.; nitrogen by the Kjeldahl method; phosphorus by the volumetric method; and

mechanical analysis by E. Troell's modification of the G. W. Robinson method (*8*), adapted to the U.S. Bureau of Soils' classification of soil separates.

The location and description of each sample is given in Table 2. The drift material, as would be expected, consists of finer structural aggregates than are found in the related soils. The majority of the samples, both of soil and drift, are calcareous, as shown by their reaction to dilute HCl.

TABLE 2. LOCATION AND DESCRIPTION OF SAMPLES

Sample	Location	Series	Texture	Structure	Effervescence (HCl)
9-Soil	Richlea	Sceptre	Heavy clay	Large granular—cloddy	Moderate
9-Drift	Richlea	Sceptre	Heavy clay	Fine granular—cloddy	Moderate
10-Soil	Sanctuary	Sceptre	Heavy clay	Fine granular—nutty	Moderate
10-Drift	Sanctuary	Sceptre	Heavy clay	Granular—cloddy	Moderate
12-Soil	Kyle	Sceptre	Heavy clay loam clay	Granular—cloddy	Moderate
12-Drift	Kyle	Sceptre	Sandy clay	Granular—single grain	Moderate
8-Soil	Ridpath	Regina	Heavy clay	Granular—cloddy	Moderate
8-Drift	Ridpath	Regina	Heavy clay	Granular	Slight
14-Soil	Pasqua	Regina	Heavy clay	Fine granular—cloddy	Moderate
14-Drift	Pasqua	Regina	Heavy clay	Fine granular—nutty	Moderate
16-Soil	Lumsden	Regina	Heavy clay	Fine granular—cloddy	Strong
16-Drift	Lumsden	Regina	Heavy clay	Fine granular	Moderate
18-Soil	Wheatstone	Regina	Clay	Med. granular—cloddy	Slight
18-Drift	Wheatstone	Regina	Clay	Fine granular—nutty	Moderate
22-Soil	Beatty	Melfort	Silty clay loam	Granular—small cloddy	None
22-Drift	Beatty	Melfort	Silty clay loam	Granular	Moderate
23-Soil	Indian Head	Indian Head	Clay	Granular—cloddy	Moderate
23-Drift	Indian Head	Indian Head	Clay	Fine—med. granular	Moderate
2-Soil	Fox Valley	Fox Valley	Silty clay loam	Granular—cloddy	Faint
2-Drift	Fox Valley	Fox Valley	Clay loam (silty)	Fine granular	Slight
3-Soil	Shaunavon	Haverhill	Heavy loam	Granular—cloddy	Faint
3-Drift	Shaunavon	Haverhill	Light loam	Granular—single grain	Faint
4-Soil	Lakenheath	Haverhill	Clay loam	Fine granular—cloddy	Faint
4-Drift	Lakenheath	Haverhill	Light loam	Granular—single grain	Faint
7-Soil	Harris	Elstow	Clay loam (silty)	Granular—cloddy	None
7-Drift	Harris	Elstow	Clay loam (silty)	Granular	Faint
15-Soil	Briercrest	Weyburn	Heavy loam	Granular—cloddy	None
15-Drift	Briercrest	Weyburn	Light loam	Granular—single grain	None
17-Soil	Holdfast	Weyburn	Loam	Granular—cloddy	Moderate
17-Drift	Holdfast	Weyburn	Light loam	Granular—single grain	Faint
19-Soil	Parry	Weyburn	Clay loam	Granular—cloddy	None
19-Drift	Parry	Weyburn	Sandy loam	Granular—single grain	None
20-Soil	Talmage	Weyburn	Clay loam	Granular—platy	None
20-Drift	Talmage	Weyburn	Loam	Fine granular	None

TABLE 2.—LOCATION AND DESCRIPTION OF SAMPLES—*Concluded*

Sample	Location	Series	Texture	Structure	Effervescence (HCl)
1-Soil	Kingsland	Weyburn	Loam, silty	Granular—cloddy	None
1-Drift	Kingsland	Weyburn	Loam, silty	Fine granular—single grain	None
5-Soil	Lake Johnston	Hatton	Light fine sandy loam	Single grain—granular	Faint
5-Drift	Lake Johnston	Hatton	Sand	Single grain	Faint
13-Soil	Mortlach	Hatton	Light sandy loam	Cloddy—nutty	None
13-Drift	Mortlach	Hatton	Sand	Single grain	None
11-Soil	Kyle	Haverhill	Light loam	Granular nutty	None
11 Drift	Kyle	Haverhill	Heavy sandy loam	Granular—single grain	None
21-Soil	Carnduff	Asquith	Fine sandy loam	Fine grain	Slight
21-Drift	Carnduff	Asquith	Light sandy loam	Coarse grain	Moderate
24-Soil	Lanigan	Asquith	Sandy loam	Single grain - soft clod	None
24-Drift	Lanigan	Asquith	Sand	Single grain	None

There is no indication that the drift tends to be more calcareous than the soil or vice versa; nor can it be stated that the drifting soils are necessarily calcareous, since approximately one-third of the samples showed no effervescence with acid. It may be noted that the clay soils and those of medium texture having a relatively high silt content, show little or no textural difference between the original soil and its related drift On the other hand the drift from the medium glacial soils and the light soils is distinctly lighter in texture than the original soil.

The drift samples, when air dried, appeared in many cases to be slightly darker in colour than the corresponding soils. Except in a few cases, as noted later, the data for loss on ignition and nitrogen do not indicate that the darker colour is due to a higher content of organic matter in the drift. The pH of the samples varies from 6 8 to 8, with no distinct differences in reaction showing between soil and drift.

Mechanical Analysis of Soil and Drift Samples

The textural relationship between soil and drift is shown definitely in Table 3, which contains the results of mechanical analyses determined on all samples. The figures for hygroscopic moisture, loss on ignition, total nitrogen and phosphorus are also given, and these will be discussed later. The samples are placed in the same order as in the preceding table, the heavy soils being placed first, followed by those of medium and light textures.

Referring to the data on mechanical analysis, it will be seen that as mentioned above, there is little difference between the textural composition of the clay soils and their related drift materials. The soils have a clay content of from 35 to 84%, (using round figures) a silt content of from 7 to 28%, and a sand content of from 2 to 43%. The drift samples, in comparison have 32 to 83% clay, 8 to 31% silt, and from 2 to 53% sand.

TABLE 3.—ANALYSES OF SOIL AND DRIFT SAMPLES

Sample	Texture	Mechanical Analysis			Chemical Analysis			
		% Clay	% Silt	% Sand	% H_2O	% Ign loss	% N	% P
9-Soil	Heavy clay	84.3	7.0	2.2	8.40	7.09	0.237	0.062
9-Drift	Heavy clay	83.2	7.8	1.6	8.42	6.96	0.236	0.058
10-Soil	Heavy clay	70.3	15.8	4.6	7.24	7.99	0.237	0.082
10-Drift	Heavy clay	69.9	15.8	4.5	7.83	6.75	0.216	0.080
12-Soil	Clay	34.9	14.3	42.8	3.92	5.8	0.206	0.038
12-Drift	Sandy clay	32.2	10.5	53.2	3.29	4.53	0.158	0.030
8-Soil	Heavy clay	58.9	24.9	7.3	5.85	6.49	0.274	0.071
8-Drift	Heavy clay	55.6	31.2	6.8	5.25	7.04	0.266	0.067
14-Soil	Heavy clay	74.1	16.1	2.5	7.18	7.66	0.254	0.068
14-Drift	Heavy clay	72.5	15.7	2.8	6.89	7.69	0.251	0.068
16-Soil	Heavy clay	66.8	24.7	4.2	6.15	5.45	0.161	0.064
16-Drift	Heavy clay	61.3	26.9	4.5	6.16	7.20	0.260	0.076
18-Soil	Clay	46.1	27.8	14.2	4.93	8.04	0.308	0.083
18-Drift	Clay	49.3	22.4	19.1	4.73	7.15	0.280	0.073
22-Soil	Heavy silty clay loam	51.0	28.1	8.1	5.17	11.45	0.637	0.115
22-Drift	Heavy silty clay loam	56.6	29.1	7.8	5.21	12.97	0.538	0.114
21-Soil	Clay	58.6	20.3	5.6	6.29	10.23	0.381	0.083
21-Drift	Clay	63.9	20.0	6.3	6.57	10.13	0.374	0.116
2-Soil	Clay loam, silty	23.9	41.1	32.2	2.63	5.00	0.171	0.051
2-Drift	Clay loam, silty	23.4	37.0	39.8	3.22	7.28	0.382	0.058
3-Soil	Heavy loam	22.5	36.8	36.7	2.78	5.72	0.259	0.083
3-Drift	Light loam	19.45	18.9	60.0	1.78	3.67	0.149	0.040
4-Soil	Clay loam	24.2	26.2	40.1	2.57	4.90	0.193	0.069
4-Drift	Light loam	20.2	11.2	66.2	1.91	3.30	0.099	0.043
7-Soil	Clay loam, silty	25.9	43.4	21.1	3.09	5.95	0.242	0.074
7-Drift	Clay loam, silty	25.4	38.6	32.2	2.71	5.37	0.222	0.061
15-Soil	Loam	22.5	33.2	36.8	2.7	5.64	0.241	0.048
15-Drift	Light loam	26.4	10.9	58.9	2.27	3.97	0.160	0.043
17-Soil	Loam	21.5	33.9	37.6	2.63	5.71	0.245	0.069
17-Drift	Light loam	19.8	26.9	48.6	2.55	6.61	0.302	0.064
19-Soil	Clay loam	27.3	29.8	38.4	2.69	6.74	0.203	0.075
19-Drift	Lt loam—sandy loam	1.9	27.5	69.1	1.53	2.51	0.099	0.039
20-Soil	Clay loam	27.6	34.6	34.2	3.17	7.41	0.294	0.072
20-Drift	Loam	26.1	23.4	47.8	2.73	6.14	0.251	0.068
1-Soil	Hvy loam, silty	22.6	39.0	29.6	[illegible].95	8.95	0.379	0.079
1-Drift	Hvy. loam, silty	22.2	40.2	31.6	[illegible].99	9.80	0.432	0.097
5-Soil	Light sandy loam	8.1	8.9	80.8	1.13	2.49	0.153	0.045
5-Drift	Sand	2.5	0.7	93.5	0.36	0.83	0.040	0.024
13-Soil	Light sandy loam	15.8	2.5	79.4	1.75	2.02	0.066	0.023
13-Drift	Sand	6.0	8.3	91.1	0.55	1.09	0.050	0.016
11-Soil	Light loam	25.9	20.5	44.6	2.44	5.59	0.205	0.042
11-Drift	Hvy. sandy loam	25.7	9.6	64.6	2.61	4.21	0.153	0.039

TABLE 3.—ANALYSES OF SOIL AND DRIFT SAMPLES—*Concluded*

Sample	Texture	Mechanical Analysis			Chemical Analysis			
		% Clay	% Silt	% Sand	% H_2O	% Ign. loss	Nitrogen	P
21–Soil	Sandy loam	11 7	13 6	72 8	1 75	4 21	0 194	0 056
21 Drift	Light sandy loam	10 7	8 6	78 3	1 16	3 09	0 151	0 061
24–Soil	Sandy loam	6 9	13 4	75 6	1 15	4 58	0 238	0 040
21 Drift	Sand	2 3	1 8	95 6	0 25	1 21	0 067	0 014

In the medium textured samples analyzed, the clay content ranges from 21.5 to 27 6% for the soils, and from 1.9 to 26% for the drift. The silt content in the soil varies from 26 to 44%, in the drift from 11 to 40%. The sand content in the soil varies from 21 to 40%, in the drift from 31 to 69%. The clay content is highest in the soil, except in the case of Sample 15 but the differences are not great except for Sample 19. The silt content is considerably higher in the soil than in the drift; the sand is always higher in the drift and generally the difference is considerable. Samples 1, 2 and 7, representing medium heavy silty types, show less difference between the soil and drift than is the case with the remaining samples, which are of glacial origin. It should be mentioned that in order to save time the sand was not separated into its various fractions. Observations of the total sand fractions of the above silty types and also of the heavy samples showed that they were predominantly very fine sand.

For the medium textured samples the potential value of the drift materials as indicated by the textural character is in all cases poorer than for the original soils, due to the increase in the sand fraction. In six of the samples the drift contains from 50 to 66% sand, thus putting the samples into the sandy loam class. The clay content is high enough in most cases to give a textural "feel" of a light loam.

The light soils, as would be expected, show a complete contrast in mechanical composition to the heavy soils. In the latter the clay is the dominant fraction, while in the light soils the sand is present in greatest amount

In the case of the sandy loams, the soils contain from 72 to 81% sand; the drift samples from 78 to 96% sand. The silt and clay fractions, though present in much smaller percentages than in the heavier samples, exhibit great variation between soil and drift.

The clay content of these soils varies from 6.9 to 15 8%; of the drift from 2 3 to 10 7%. The silt content of the soil ranges from 2 5 to 13.6%; of the drift from below 1% to 8 6%. The clay and silt are always higher in the soil than in the related drift. Sample 11, which is bordering on the sandy loam class, has about the same clay content in soil and drift; the silt content of the soil is double that of the drift, however, and the drift contains 20% more sand than the soil. Sample 13 is interesting in that it is really a subsoil and represents the residual material after at least three and one-half feet of top soil have been blown away. This explains its relatively high clay content.

TABLE 4.—AVERAGE MECHANICAL COMPOSITION OF HEAVY, MEDIUM AND LIGHT SAMPLES OF SOIL AND DRIFT

Samples	% Clay	% Silt	% Sand
Clay Soils (9 samples)	60 5	19 86	10 20
Drift from Clay Soils (9 samples)	60 5	19 90	10 70
Clay loam and loam soils (9 samples)	24 22	35 66	34 10
Drift from Clay Loam and loam Soils (9 samples)	20 50	26 10	50 40
Sandy Loam Soils (5 samples)	13 60	11 70	70 00
Drift from sandy Loams (5 samples)	9 40	5 80	84 60

The differences in mechanical composition between the soil and drift in heavy, medium and light textured samples are summarized in Table 4. The average content of clay, silt and sand of all the heavy soils, together with that of the corresponding drift materials are shown first, followed by similar data for the medium and light textured soils and their related drift materials

This table indicates that the average mechanical composition of the heavy soils and drifts is almost identical, furthermore, both soil and drift must be placed in the clay class The medium textured soils theoretically average a clay loam, but the related drift can only be considered a light loam. The light textured soils as averaged have the composition of a sandy loam, while the average of the related drift materials is merely a sand. The above differences in mechanical composition of the samples are also shown graphically in Figure 2.

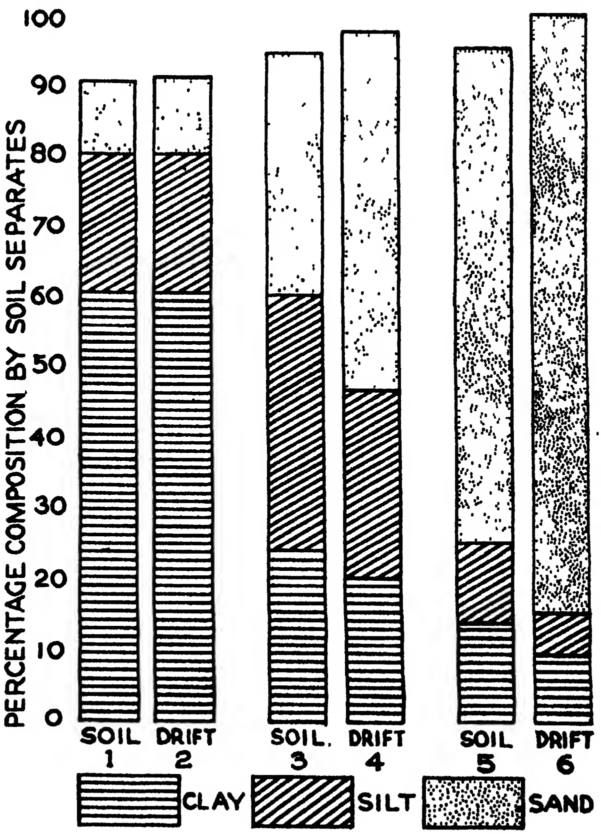

FIGURE 2.—Average percentage composition by soil separates of heavy, medium and light samples of soil and drift. 1, clay soils; 2, drift from clay soils; 3, clay loam and loam soils; 4, drift from clay loams and loams; 5, sandy loams; 6, drift from sandy loams.

These results suggest that the clay soils drift in the form of a granule or compound particle having essentially the same mechanical composition as the soil as a whole. In the medium and light textured soils there is apparently a definite sorting out of the sand fraction, whereby the drift is higher in sand and correspondingly lower in clay and silt than the soil. Some of the clay and silt blown out of the medium and light soils is apparently not deposited with the more sandy drift, but is presumably carried by the wind to a greater distance.

Chemical Analysis of Soil and Drift Samples

Referring again to Table 3, the figures for hygroscopic moisture, loss on ignition, nitrogen and phosphorus, furnish additional data on the differences between soil samples and the corresponding drift materials. The figures for hygroscopic moisture give a rough idea of the relative amounts of colloidal material present In general, higher figures for hygroscopic moisture correspond to higher percentages of clay and silt. The highest figure for moisture (8 4%) is found in Sample 9, a heavy soil

FIGURE 3 -A good stand of wheat on drifted Regina clay.

FIGURE 4.—The remains of a cultivated field of Hatton sandy loam, the surrounding soil having drifted down 3½ feet.

of the Sceptre series having a clay content of over 80%. The lowest figure for moisture is 0.25%, found in a drift sample of the Asquith sandy loam which contains over 95% sand. The medium and light textured samples, which exhibit the greatest differences in mechanical composition between soil and drift, also show greater differences in moisture content as compared with the heavy samples.

While it is recognized that the determination of loss on ignition as a measure of the organic matter content is open to serious error, in this study the determination agrees fairly well with the known facts regarding the organic matter content of Saskatchewan soils. The agreement between loss on ignition and nitrogen is generally satisfactory. In practically all cases, both in soil and drift samples, higher loss on ignition values correspond with higher percentages of nitrogen. In most of the samples the ignition and nitrogen values are higher in the soil than in the related drift. Notable exceptions to this occur in the data for Samples 1 and 2, in which the reverse is true. In both these cases the drift sample was found to

FIGURE 5.—A combination of wind and water erosion of Haverhill clay loam and loam.

FIGURE 6.—Wind erosion in uncultivated sand dune area, adjacent to abandoned field carrying sweet clover and brome grass.

contain considerable undecomposed plant material, in such a fine state of division that it could not be properly separated from the mineral soil. Samples 16 and 17 also show higher ignition and nitrogen values in the drift, but the cause in this case was not apparent.

The nitrogen content is not excessively low except in the sandy drifts (Samples 5, 13 and 24) and in the exposed subsoil in Sample 13. Only two medium textured drifts (4 and 19) have a nitrogen content below 0 1%. Values for loss on ignition and nitrogen are highest in the heavy black park soil of the Melfort series, represented by Sample 22. In this soil the ignition loss is 14 45% and the figure for nitrogen is 0 637%. The drift in this same sample has an ignition loss of 12 97%, while the nitrogen value is 0 538%.

In distinct contrast to these figures, the lowest results occur in a sandy soil of the brown prairie zone, represented by the Hatton series (Sample 5), the soil has an ignition loss of 2 49% and a nitrogen content of 0.153%. The drift has an ignition loss of 0 83% while the figure for nitrogen is 0 04%. It is thus interesting to note that the highest loss on ignition figures coincide with the highest values for nitrogen, and conversely, the lowest loss on ignition is found in the samples having the lowest figures for nitrogen.

The Melfort series referred to above, together with the Indian Head series (Sample 23), represent the heavy textured fertile soils of the sub-humid black park zone. The figures for loss on ignition and nitrogen indicate a much higher content of organic matter than is found in the soils of the semi-arid brown prairie zone. This fact supports the view suggested in the discussion of the field observations above, namely, that a high content of organic matter, largely in the form of humus or decomposed organic matter, is no assurance that a soil will not drift. Harrison (3) found little relation between loss on ignition and tendency to drift in Manitoba soils, and suggested that drifting was caused by the absence of fibre.

The results of the phosphorus determinations show the same general trend as the values for the nitrogen, particularly where the latter is present in relatively high amounts. The highest values for phosphorus occur in the Melfort and Indian Head soils (samples 22 and 23) while the lowest values are found in the sandy drifts from the Hatton and Asquith fine sandy loams (Samples 13 and 24).

The phosphorus values do not follow the same order as those of nitrogen in all cases, however. The data in Table 3 indicate that there is a general tendency for lower phosphorus figures in those samples relatively high in sand.

The percentages of nitrogen and phosphorus present in the soil samples of the normally productive heavy and medium types indicate that these soils are potentially very fertile. The cause of the present drifting condition of these soils is not due therefore to their having become "worn-out" or "run-down" agriculturally, as some have asserted. In so far as laboratory analysis is an index of soil fertility, the figures for mechanical analysis, moisture and loss on ignition give additional support to the conclusions drawn from the values for nitrogen and phosphorus.

The data for hygroscopic moisture, ignition, nitrogen and phosphorus are summarized in Table 5, which gives the average figures for these determinations in heavy, medium and light soils and the corresponding drifts.

TABLE 5.—AVERAGE CHEMICAL COMPOSITION OF HEAVY, MEDIUM AND LIGHT SAMPLES OF SOILS AND DRIFT

Samples	% H_2O	% Ign. loss	% N	% P
Clay Soils (9 samples)	6 12	8 13	0 324	0 073
Drift from Clay Soils (9 samples)	6 04	7 82	0 308	0 076
Clay loam and loam soils (9 samples)	2 80	6 22	0 238	0 069
Drift from clay loam and loam soils (9 samples)	2 42	5 63	0 233*	0 055
Sandy loam soils (5 samples)	1 64	3 78	0 171	0 041
Drift from sandy loam soils (5 samples)	0 98	2 08	0 092	0 031

*The relatively high percentage of nitrogen in the medium drift is due to the inclusion of the abnormal nitrogen values of the drifts from Samples 1 and 2. Excluding these samples the average percentage would be 0 183

CONCLUSIONS

The laboratory data presented above confirm the field observations made with respect to soil drifting in Saskatchewan. The drifted material from heavy soils is practically identical in mechanical composition with the undrifted soil. The same is true generally for the values for hygroscopic moisture, loss on ignition, nitrogen and phosphorus. On the other hand the drift from sandy soils has a much lighter texture and lower values for the above constituents than the undrifted soil The drift from medium textured glacial types is also lighter than the original soil, but is potentially more fertile than the drift from sandy soils.

While much of the drifted material is piled along fences and roadsides, a considerable amount is also deposited in cultivated fields. It is obvious that if a normally productive field receives a deposit of drift from a sandy soil, the fertility of such land may be seriously impaired or even permanently destroyed. In addition to the above factor there is another reason why light soils constitute the most serious problem of soil drifting. In many areas the natural surface soil has been eroded by wind to such an extent that the sandy subsoil, low in organic matter and natural fertility is exposed as the present surface. Sample No 13 is an example of this condition, and from the standpoint of soil fertility both soil and drift are of low agricultural value Finally, it may be pointed out that sandy loam soils of semi arid regions cannot be considered good agricultural soils, apart from their tendency to drift, on account of their relatively low moisture holding capacities.

It has been shown that the problem of drifting on the light soils is a serious one from many aspects. However, the need for measures of effective control of drifting on the heavier, more fertile soils is equally important, since such soils have a higher potential productivity than the lighter types and the losses incurred through drifting are consequently greater. The necessity of considering soil type in any investigations dealing with soil drifting is evident.

SUMMARY

1. Observations made in Saskatchewan during the summer of 1934 indicate that soil drifting or wind erosion is generally most severe on the very heavy and the very light soils. Similar observations were made several years ago during the course of the soil survey work. There is, however, a definite tendency during the present period of drought for serious drifting to develop on medium-textured soils formerly classed as relatively non-drifting types.

2. The investigations indicate that serious drifting is occurring on a number of soil series, representing a variety of soil textures, parent materials and zones.

3. The occurrence of soil drifting in the black park zone indicates that the presence of a high content of humus or decomposed organic matter does not prevent a soil from drifting.

4. The analyses show that the clay soils and the corresponding drifted materials are practically identical in composition. Soil drift from sandy loam areas is poorer in textural grade and chemical composition than the original soil. Drift from medium textured soils exhibits a similar tendency, but the differences between soil and drift are not so great.

5. The analytical data suggest that the samples of heavy and medium textured soils are potentially quite fertile. There is no indication that the present tendency of these soils to drift is due to any serious loss in their productive capacities.

6. While the investigation indicates that the soil drifting problem is most serious on the lighter soil types, the heavier soils also demand attention since they are much more valuable agriculturally.

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REFERENCES

1. Bracken, John. The management of drifting soils Field Husbandry Cir no. 28. Saskatchewan Department of Agriculture
2. Department of Soils, University of Saskatchewan. Soil Survey Reports Nos 1 to 9. 1923-31.
3. Harrison, T J. The maintenance of soil fibre. Conservation of soil fertility and soil fibre. Comm. of Conservation, Canada, p. 63-68. 1920.
4. Joel, A. H. Predominant Saskatchewan soil profiles correlated with soil development factors in northern latitudes. Proc. and Papers First Inst Cong. Soil Sci 1927.
5. ——— Genesis and morphology of cool climate semi-arid soils in Saskatchewan, Canada Am Soil Surv Assoc Bulletin 12. 1932
6. ——— The zonal sequence of soil profiles in Saskatchewan, Canada. Soil Sci. *36* . 173-187. 1933.
7. Province of Saskatchewan Report of the Royal Commission of Inquiry into Farming Conditions. 1921.
8. Troell, Erik. The use of sodium hypobromite for the oxidation of organic matter in the mechanical analysis of soils. Journ. Agr. Sci. *21* : 476-483. 1931
9. Wyatt, F. A. *et al.* Soil drifting and its control. University of Alberta, College of Agriculture Circ. No. 13. 1932.

Résumé

Quelque études dans le champ et au laboratoire des tourbillons de poussière en Saskatchewan. H. C. Moss, Université de la Saskatchewan, Saskatoon, Sask.

Des observations faites en Saskatchewan pendant l'été de 1934 montrent que les tourbillons de poussière, c'est-à-dire l'érosion du sol par le vent, sont généralement plus graves sur les sols très lourds et très légers qu'ailleurs. Il a été fait des observations du même genre, il y a plusieurs années, au cours de l'étude des sols. Cependant pendant la période actuelle de sécheresse, on constate une tendance bien nette à la marche de l'érosion sur les sols de texture moyenne, autrefois classés parmi les types qui ne se soulèvent pas au vent. Les recherches indiquent qu'une grave érosion se produit sur un certain nombre de sols de texture variée, différents au point de vue des matériaux de formation et des zones. L'érosion par le vent dans la zone noire des parcs indique que la présence d'une haute proportion d'humus ou de matière organique décomposée n'empêche pas le sol de se soulever au vent. Les analyses montrent que les sols d'argile et les matériaux correspondants qui en proviennent sont d'une composition à peu près identique. Les matériaux enlevés par le vent des sols sablo-argileux sont plus pauvres en texture et en composition chimique que le sol original. Les matériaux provenant des sols à texture moyenne exhibent une même tendance mais les différences entre le sol et les matériaux enlevés ne sont pas aussi grandes. Les données des analyses portent à croire que les échantillons de sol à texture lourde et moyenne sont potentiellement très fertiles. Il n'y a aucune indication que la tendance actuelle à l'érosion soit due à une diminution sérieuse de leur capacité de production. Les recherches qui ont été faites indiquent que le problème de l'érosion est surtout grave sur les types de sol plus légers, mais les sols plus lourds exigent également de l'attention car ils ont plus de valeur au point de vue agricole.

A COMPARISON OF DIFFERENT TYPES OF ROOT ROT OF WHEAT BY MEANS OF ROOT EXCAVATION STUDIES[1]

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INTRODUCTION

Several papers concerning the normal development of Marquis wheat (*9*) and its responses to artificial amputation of different parts of the root systems (*7, 8*) have already been published by Simmonds and Sallans. The present paper deals with root excavation studies of Marquis wheat when attacked by different types of root rot in the field. This method of studying root-rot problems has yielded valuable information concerning the position and extent of the injury to the root systems of wheat from diseases of this kind.

MATERIALS AND METHODS

Fields were selected in which natural infections of the various root rots had developed. Beginning with the seedling stage the main roots of a number of typically diseased plants were excavated by Weaver's method (*12*). Data relating to the development of the whole plant, and to the position and extent of typical lesions on the roots and stem bases were taken. At the same time plants of healthy appearance were selected close at hand and similar data concerning these were taken. The actual lengths and the courses followed by the main roots were ascertained definitely but it was almost impossible to excavate the branch rootlets fully by the method used. A large number of the excavated roots were examined microscopically for signs of the various pathogens primarily responsible for the diseased condition. Similar excavations and examinations were made in the same fields at midseason and just previous to the maturity of the wheat. In most cases small blocks of earth containing additional plants were dug out and the earth was washed from their roots. In this way supplementary data on relative numbers and infection of lateral rootlets were obtained. Measurements of the height of the plants were made from the seed level to the tip of the tallest leaf in the seedling and midseason stages, and to the tip of the tallest head at the mature stage. In several instances the investigation was complicated by the fact that more than one type of root rot were present on the plants selected for study but in such cases the type being studied was much more in evidence than the others. Moreover, it was nearly impossible to find perfectly healthy specimens, but the plants designated as healthy in this paper were only slightly affected by any of the root rots.

In referring to the roots and basal parts of the wheat plant the same nomenclature is used as that employed in previous articles of this series. All of the roots arising at the lower end of the subcrown internode are

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[2] Senior Plant Pathologist, Plant Pathologist and Assistant Plant Pathologist, respectively.

classed as seminal roots. At the same time it is thought that a small proportion of these roots are not true seminal roots because their primordia are never visible in sections of the resting embryo and they emerge just above the attachment of the coleoptile instead of just below it. Percival (*4*) calls these roots the "coleoptile pair" and McCall (*2*) refers to them as "coleoptile axillary roots" and states that there may be as many as three of these on one plant. During these studies it was found that there was, on the average, approximately one coleoptile axillary root per plant.

TYPES OF ROOT ROT STUDIED

The root rots of cereals, prevalent in Saskatchewan, may be divided into several distinct types. The three types which are of greatest economic importance at the present time are "common root rot," "take-all" and "browning root rot."

Common root rot usually is caused by *Helminthosporium sativum* P.K. & B. and by *Fusarium* spp. in this region. This disease may arise either from seed-borne infection or from the causal organisms living in the soil. The symptoms consist of brownish lesions on the roots, subcrown internodes, crowns, bases of the culms, and sheaths of the lower leaves, together with more or less severe stunting (*1*). Under moist conditions, signs of the causal organisms, in the form of mycelia and conidia, may be found developing in and on the affected parts. Under Saskatchewan conditions this disease usually does not produce an appreciable amount of seedling blight. As a rule the plants live through to maturity but the yield of grain is reduced. More or less of this disease is present annually in practically every field of wheat throughout the province.

Take-all is a root rot caused primarily by *Ophiobolus graminis* Sacc. In typical cases it is easily distinguished from the other types found in this region by the distinct blackening of the affected parts and by the presence of the characteristic brown mycelium of the causal organism (*5*). Plants severely affected with take-all usually die before reaching maturity. In the field this disease is more severe in comparatively wet seasons. Under dry conditions the symptoms are less conspicuous and the blackening and decay are mainly confined to the seminal roots and the subcrown internode. This has been termed "dry-weather take-all" (*6*). Take-all is most prevalent in comparatively new fields in districts which are fairly well wooded.

Browning root rot is caused primarily by *Pythium* spp. (*10*). In the seedling stage of wheat this disease is characterized by yellowing and death of the lower leaves followed by discolorations in which brown shades predominate. At the same time the seedlings become unthrifty and stunted. The laterals of the seminal roots, when examined under the microscope, present a discoloured, sickly appearance and many of the crown roots are cut off by severe lesions within a few inches of the crown. The diseased laterals and the crown roots at the points where they are rotted off usually contain an abundance of *Pythium* oospores (*11*). The diseased plants rarely die but recover to some extent as the surviving crown roots become established. The plants regain their green colour but remain more or less stunted and spindly right through to maturity. Maturity is delayed and

yields are reduced. Browning root rot is widely distributed throughout the province of Saskatchewan. This disease is most noticeable in wheat grown on summer-fallow, but it is not confined to such fields.

The causal organisms of these three types of root rot belong to widely different groups of fungi. Various methods of control must be employed to deal effectively with the different types. The symptoms of the three types described in this paper differ in many respects. The excavation studies described below help to explain why some of these differences exist.

EXCAVATION STUDIES

Common root rot

The excavations of plants affected by common root rot were made in 1933 and 1934 at Indian Head, Saskatchewan. As the development of the normal plant and of the disease are both affected by the environmental conditions, brief descriptions of the weather conditions prevailing during the two growing seasons in question are given.

TABLE 1.—DATA SHOWING THE TOTAL MONTHLY PRECIPITATION AND THE MEAN AIR TEMPERATURES FOR THE MONTHS OF APRIL, MAY, JUNE AND JULY, AT THE THREE POINTS WHERE EXCAVATION STUDIES WERE CONDUCTED. TEN-YEAR AVERAGES OF SIMILAR DATA ARE GIVEN FOR COMPARISON

Place	Year	Precipitation					Mean monthly air temperatures				
		April	May	June	July	4-mo Total	April	May	June	July	4-mo. average
		inches	inches	inches	inches	inches	° F	° F.	° F	° F	° F
Indian Head	1933	1.54	4.23	3.22	0.86	9.85	34.9	53.2	64.1	65.7	54.5
	1934	0.28	0.67	2.89	1.15	4.99	39.9	57.1	58.6	66.3	55.5
	10-year ave (1922-1931)	0.82	1.67	3.02	1.96	7.47	37.3	49.8	59.1	63.2	52.4
Muenster	1933	0.80	2.28	1.80	2.12	7.00	34.2	51.2	61.2	62.3	52.2
	1934	0.40	0.30	4.93	1.00	6.63	36.5	53.4	55.1	63.4	52.1
	10-year ave. (1922 1931)	0.76	1.66	2.67	2.33	7.42	36.3	49.0	57.4	62.9	51.4
Saskatoon	1933	0.39	1.90	1.00	0.98	4.27	37.8	53.5	64.3	66.8	55.6
	1934	0.79	0.39	4.01	1.09	6.28	41.4	58.6	57.5	65.8	55.7
	10-year ave (1922-1931)	0.65	1.55	2.53	1.92	6.65	38.0	50.9	59.5	65.1	53.4

The total monthly precipitation and mean monthly air temperature at Indian Head during the period from April to July, inclusive, are given in the first section of Table 1. Compared with the average data for the ten-year period of 1922 to 1931, inclusive, the precipitation for 1933 was high and that for 1934 was low. This difference in rainfall is reflected to some extent in the development of the healthy plants at maturity as shown in Table 2. Both seasons were comparatively warm.

Figures 1, 2 and 3 represent wheat plants affected with common root rot, together with typical specimens of healthy plants, produced under identical conditions. These illustrations are based on the data shown in Table 2. By the time the wheat had reached the late seedling stage

TABLE 2.—DATA SHOWING THE AVERAGE CONDITION OF PLANTS AFFECTED WITH COMMON ROOT ROT AND OF HEALTHY PLANTS GROWING NEARBY, AT THREE STAGES OF THEIR DEVELOPMENT

Condition of plants	Stage	Year	Height of plants	No. of culms		No. of leaves	Crown roots			Seminal roots					Yield of grain per plant
				With heads	Without heads		No.	Length		No.	Length				
								Range	Total		Primary	First pair	Second pair	Others	
			inches					inches	inches		inches	inches	inches	inches	grams
Diseased	Seedling	1933	9.2	1.0	0.90	8.5	3.5	0.5–2.9	6.6	3.9	9.2	8.4	1.3	0.1	—
Healthy	Seedling	1933	10.5	1.0	1.50	11.2	4.7	0.5–5.2	9.8	5.0	19.5	14.4	4.8	0.3	—
Diseased	Seedling	1934	11.0	1.0	1.20	10.6	4.6	0.5–6.1	17.8	3.2	10.1	7.7	0.6	—	—
Healthy	Seedling	1934	12.7	1.0	1.80	11.6	4.4	0.5–4.3	11.4	4.4	14.3	9.4	2.7	0.3	—
Diseased	Midseason	1934	17.2	1.0	1.80	—	5.7	1.0–11.9	30.7	4.2	14.3	16.6	5.0	1.2	—
Healthy	Midseason	1934	23.0	1.25	1.25	—	6.0	1.0–12.2	37.2	4.5	25.0	27.0	8.0	—	—
Diseased	Mature	1933	32.0	1.5	0.70	—	8.5	1.0–5.5	22.7	4.5	19.1	24.8	3.1	1.2	0.814
Healthy	Mature	1933	35.0	1.7	1.00	—	11.0	1.0–8.7	42.4	4.3	30.3	21.5	1.8	—	0.973
Diseased	Mature	1934	23.0	1.0	1.30	—	7.7	1.0–14.0	34.6	4.0	22.5	20.1	0.9	—	0.396
Healthy	Mature	1934	29.0	1.5	1.75	—	9.7	1.0–16.0	45.7	5.0	27.1	32.2	3.8	2.2	0.742

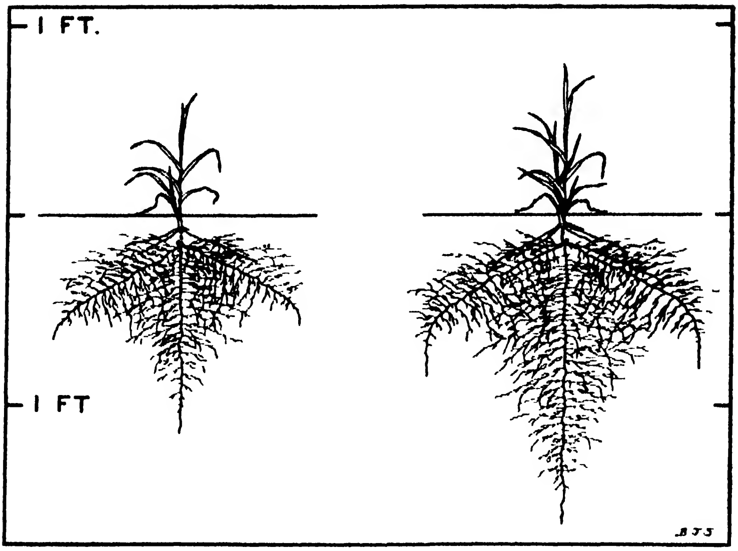

FIGURE 1. Common root rot. Semi-diagrammatic drawings of representative seedlings of Marquis wheat excavated June 20th. The affected plant is represented on the left, and the healthy one on the right. These illustrations are based on data contained in Table 2. The symptoms of common root rot at this stage are brown lesions on the subcrown internode (broken line), slight lesions on the rootlets (dotted lines) and stunting of the whole plant.

(Figure 1), the diseased plants showed pronounced lesions on the subcrown internode, the root systems were somewhat impaired and the tops were stunted. The diseased plants possessed fewer tillers and leaves than the healthy plants. By midseason (Figure 2) the difference in the extent and condition of the root systems of diseased and healthy plants was still more noticeable. The diseased plants showed more lesions on the basal parts, they had fewer culms bearing heads and their development was retarded. The plants were nearly mature by the eighth of August (Figure 3). At this time there was not much difference in the comparative development of the root systems of diseased and healthy plants as compared with the plants at midseason, but lesions on the basal parts were somewhat more pronounced. The yield of grain from the diseased plants amounted to about 70% of the yield from the healthy plants.

Take-all

The excavations connected with this study of take-all were made in the Muenster district. The data, shown in the second section of Table 1, throw some light on the weather conditions prevailing in that district during the crop seasons of 1933 and 1934. Both seasons were comparatively warm. The total precipitation for the four-month period was a little below average in both years. The distribution of the rainfall over the period in question, however, was much more uniform in 1933. Both seasons were too dry to favour the development of pronounced blackening of parts affected by the disease, therefore the plants selected for this study were mostly of the "dry-weather take-all" type.

TABLE 3.—DATA SHOWING THE AVERAGE CONDITION OF PLANTS AFFECTED WITH TAKE-ALL AND OF HEALTHY PLANTS GROWING NEARBY, AT THREE STAGES OF THEIR DEVELOPMENT

Condition of plants	Stage	Year	Height of plants	No of culms		Condition of leaves			Crown roots		Seminal roots				
				With heads	Without heads	Green	Partly green	Dead	No	Length	No	Length: Primary	Length: First pair	Length: Second pair	Length: Others
			inches							inches		inches	inches	inches	inches
Diseased	Seedling	1933	8.0	1.0	0.0	2	1	2	4	1–3.5	6	15	10.5	4.0	1.0
Healthy	Seedling	1933	11.0	1.0	1.0	5	2	1	4	1–3.0	6	18	12.5	4.5	1.0
Diseased	Midseason	1933	11.0	1.0	1.0	4	2	4	8	1–10.5	6	6	3.0	1.0	1.5
Healthy	Midseason	1933	19.5	1.0	2.0	11	5	7	15	1–8.5	6	26	16.0	6.5	2.0
Diseased	Midseason	1934	13.0	1.0	1.0	1	2	5	8	1–5.0	6	4	2.5	1.5	2.0
Healthy	Midseason	1934	27.5	1.6	1.0	4	3	6	11	1–5.5	6	25	26.0	—	3.0
						Yield of grain									
Diseased	Mature	1933	18.0	1.0	1.25	10 kernels per plant			13	1–7.0	6	2.5	2.5	1.5	1.0
Healthy	Mature	1933	35.0	2.5	1.5	60 kernels per plant			25	1–16.0	6	34	33.0	12.0	10.0
Diseased	Mature	1934	18.5	1.0	0.6	0.25 grams per plant			10	1–6.5	6	7	4.0	2.0	2.5
Healthy	Mature	1934	34.0	1.8	1.2	1.05 grams per plant			14	1–12.5	6	35	34.0	17.0	11.0

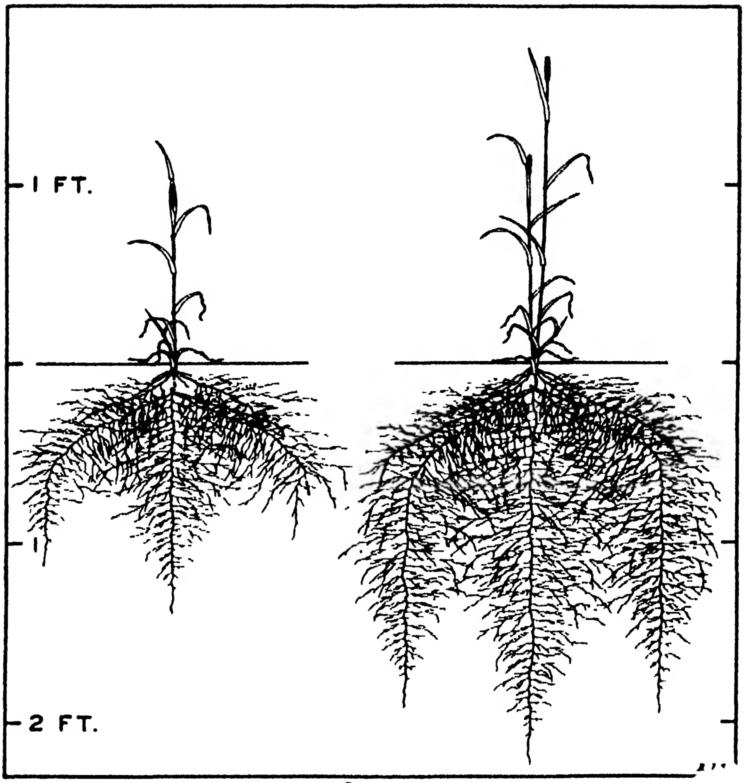

FIGURE 2. Common root rot. Semi-diagrammatic drawings of representative plants of Marquis wheat excavated July 12. The affected plant is represented on the left, and the healthy one on the right. These illustrations are based on data contained in Table 2 The symptoms of common root rot at midseason were. severe lesions on the subcrown internode and certain roots (broken lines), slight lesions on the rootlets (dotted lines) and moderate lesions at the base of the lower leaf sheaths (stippling). In addition the affected plant is stunted and retarded in its development.

Figures 4–6 illustrate the appearance, at three different stages, of wheat plants affected with take-all and of healthy plants growing within a few feet of them. The drawings are based on data summarized in Table 3. Seedling stage excavations were made about the seventeenth of June (Figure 4). The seminal roots were already severely infected close to the seed, the subcrown internodes were partially blackened, the tops of the plants were noticeably stunted and the lower leaves were prematurely dead. The crown roots of the diseased plants were considerably further advanced in proportion to the relative size of the plants than were the crown roots of the healthy ones. This tendency toward premature development of the crown roots when the seminal roots are parasitized has been noted previously (*6*). By midseason (Figure 5) the seminal roots were almost completely destroyed and only the stubs could be excavated. The subcrown internode was blackened up to the crown and many of the crown

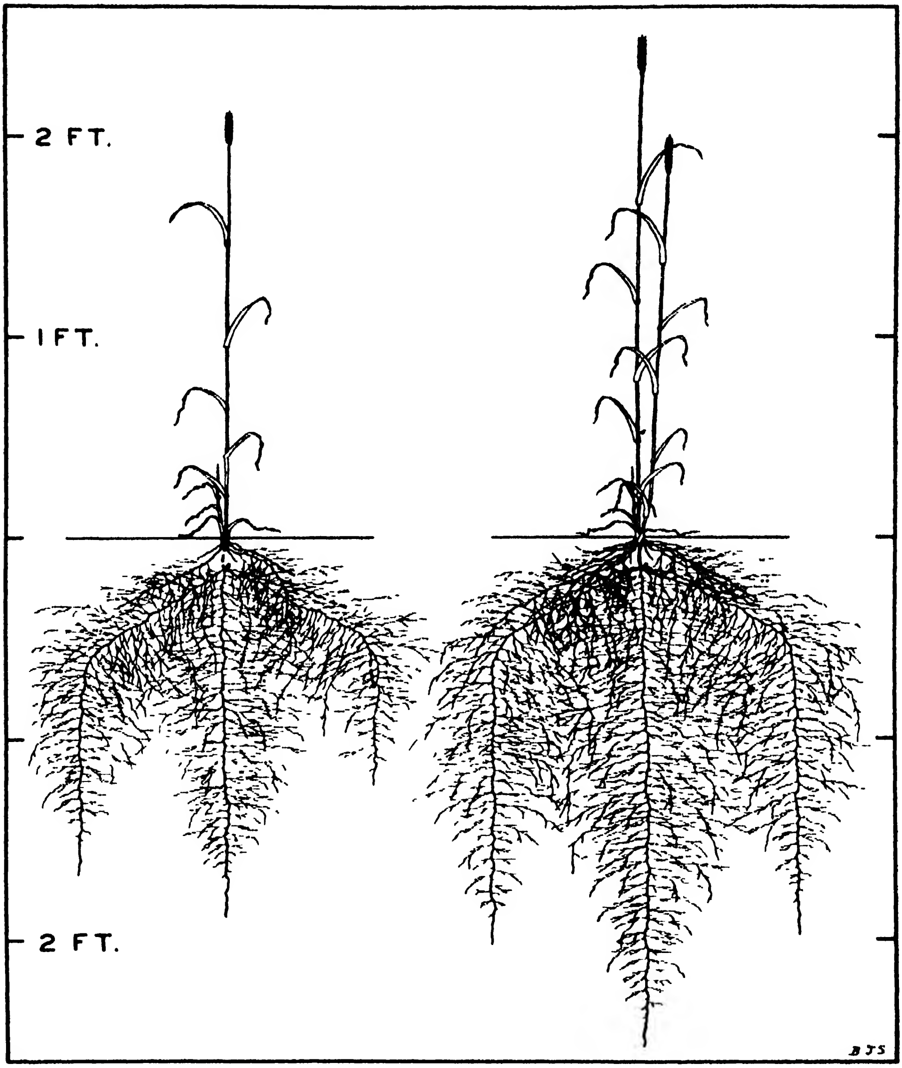

FIGURE 3. Common root rot. Semi-diagrammatic drawings of representative plants of Marquis wheat excavated August 8th. The affected plant is represented on the left, and the healthy one on the right. These illustrations are based on data contained in Table 2. The symptoms of common root rot just before the plants are mature are similar but more pronounced than those exhibited by the host of midseason. The diseased plants yield much less grain than the healthy plants do.

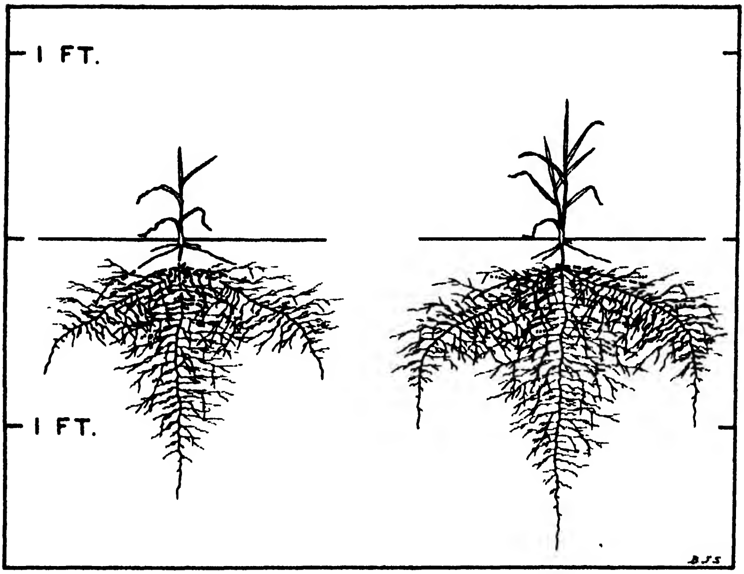

FIGURE 4. Take-all. Semi-diagrammatic drawings of representative seedlings of Marquis wheat excavated June 17th. The affected plant is represented on the left, and the healthy one on the right. These illustrations are based on data contained in Table 3 The symptoms of take-all at this stage consist of: dark brown or black lesions on the subcrown internode and seminal roots, premature death of the lower leaves, and stunting of the whole seedling.

roots had become infected. By this time the development of the crown roots of the healthy plants far surpassed that of the crown roots of the diseased plants. The tops of the diseased plants were much more stunted in comparison with those of the healthy plants than was the case in the seedling stage, and only the topmost leaves were functioning. The final excavations were made about the ninth of August, just before the healthy plants had reached maturity (Figure 6). The diseased plants had made some further progress, due to additional development of crown roots, but their tops consisted of one stunted culm and one dead tiller per plant, with a poorly developed head containing somewhat shrunken grain. The yield of grain from the diseased plants amounted to about one-fifth of that from the healthy plants.

Browning root rot

A study was made of wheat affected with browning root rot in a field near Saskatoon in 1933. Conditions were exceptionally dry, the rainfall for the months of June and July being particularly scanty. Much of this rain came in the form of light showers and a large proportion of it evaporated and did not reach the roots. As a result, the plants were unable to establish any crown roots and at maturity they were only about fourteen inches high. The yield was practically nil. Moreover, suitable healthy

TABLE 4.—DATA SHOWING THE AVERAGE CONDITION OF PLANTS AFFECTED WITH BROWNING ROOT ROT AND OF HEALTHY PLANTS GROWING NEARBY, AT THREE STAGES OF THEIR DEVELOPMENT

Condition of plants	Stage	Year	Height of plants	No. of culms		Condition of leaves			Crown roots		Seminal roots				
				With heads	Without heads	Green	Partly green	Dead	No.	Length	No.	Length: Primary	Length: First pair	Length: Second pair	Length: Others
			inches							inches		inches	inches	inches	inches
Diseased	Seedling	1933	8.5	1	0	2	1	2	1	3.0	5.5	13.0	5	1.5	0.5
Healthy	Seedling	1933	13.5	1	2	9	2	1	5	0.5–5.5	4.6	13.0	9	1.5	—
Diseased	Seedling	1934	10.5	1	0	3	2	2	5	1.0–3.5	4.5	21.5	18	5.0	2.0
Healthy	Seedling	1934	18.5	1	2	11	3	1	11	0.5–9.0	4.0	24.0	23	—	—
Diseased	Midseason	1934	19.5	1	1	4	2	5	8	0.5–9.0	5.3	31.0	23	6.0	2.0
Healthy	Midseason	1934	32.0	2	2	3	6	8	19	0.5–22.0	5.0	35.0	32	9.5	6.5
Diseased*	Mature	1933	14.2	1	0	0	2	5	3	0.5–3.0	5.3	26.0	27	5.0	5.0
Healthy	Mature	1933	—	—	—	—	—	—	—	—	—	—	—	—	—
						Yield of grain									
Diseased	Mature	1934	25.0	1	1	0.352 grams per plant			7	0.5–9.0	5.0	33.0	24	3.5	1.0
Healthy	Mature	1934	37.0	3	1	1.782 grams per plant			20	1.0–27.5	5.8	39.0	38	12.0	7.0

* These developed under severe drought. Average length of heads was only 1.4 inches.

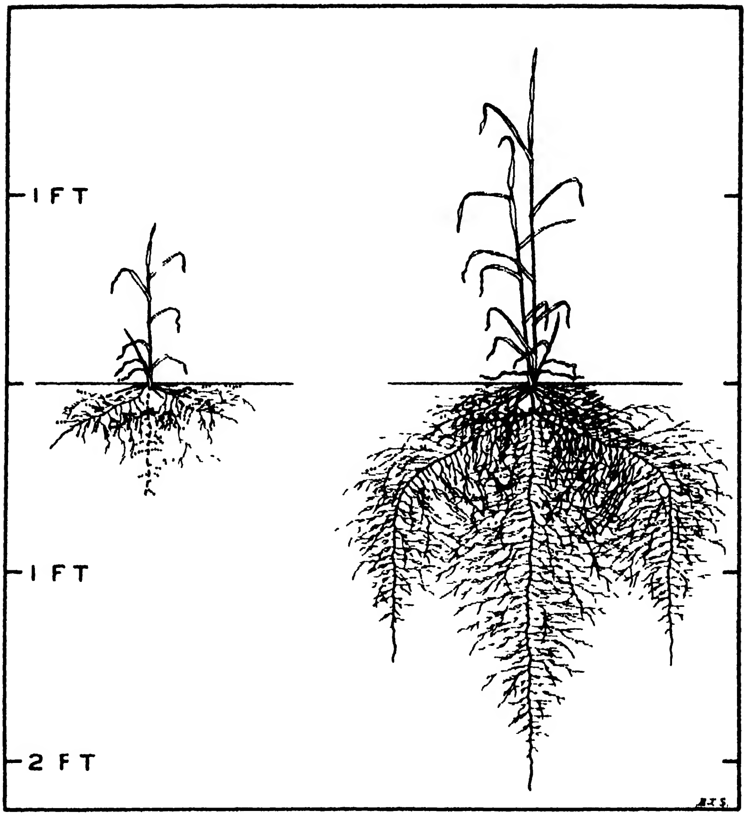

FIGURE 5. Take-all. Semi-diagrammatic drawings of representative plants of Marquis wheat excavated July 9th The affected plant is represented on the left, and the healthy one on the right. These illustrations are based on data contained in Table 3 The symptoms of the disease at midseason are. blackening and decay of the seminal roots and subcrown internode, slight lesions on the crown roots, premature death of the leaves, and marked stunting of the whole plant.

plants could not be obtained in this field. Therefore, although certain data concerning these plants are included in Table 4, they were not used in making the drawings shown in Figures 7-9. The illustrations are based on excavation studies conducted at Lanigan the following year. As Lanigan is near Muenster, the description of the weather conditions in 1934 in the foregoing section on take-all will suffice for both places.

The general effect of browning root rot on the wheat plant is illustrated in Figures 7-9. In the seedling stage (Figure 7) the attack of *Pythium* spp. centered first on the laterals of the early seminal roots and the tips and laterals of the later seminal roots. As the crown roots developed, gross lesions cut off many of them near the crown of the plant. The tops of the seedlings were stunted, and premature yellowing and death followed by

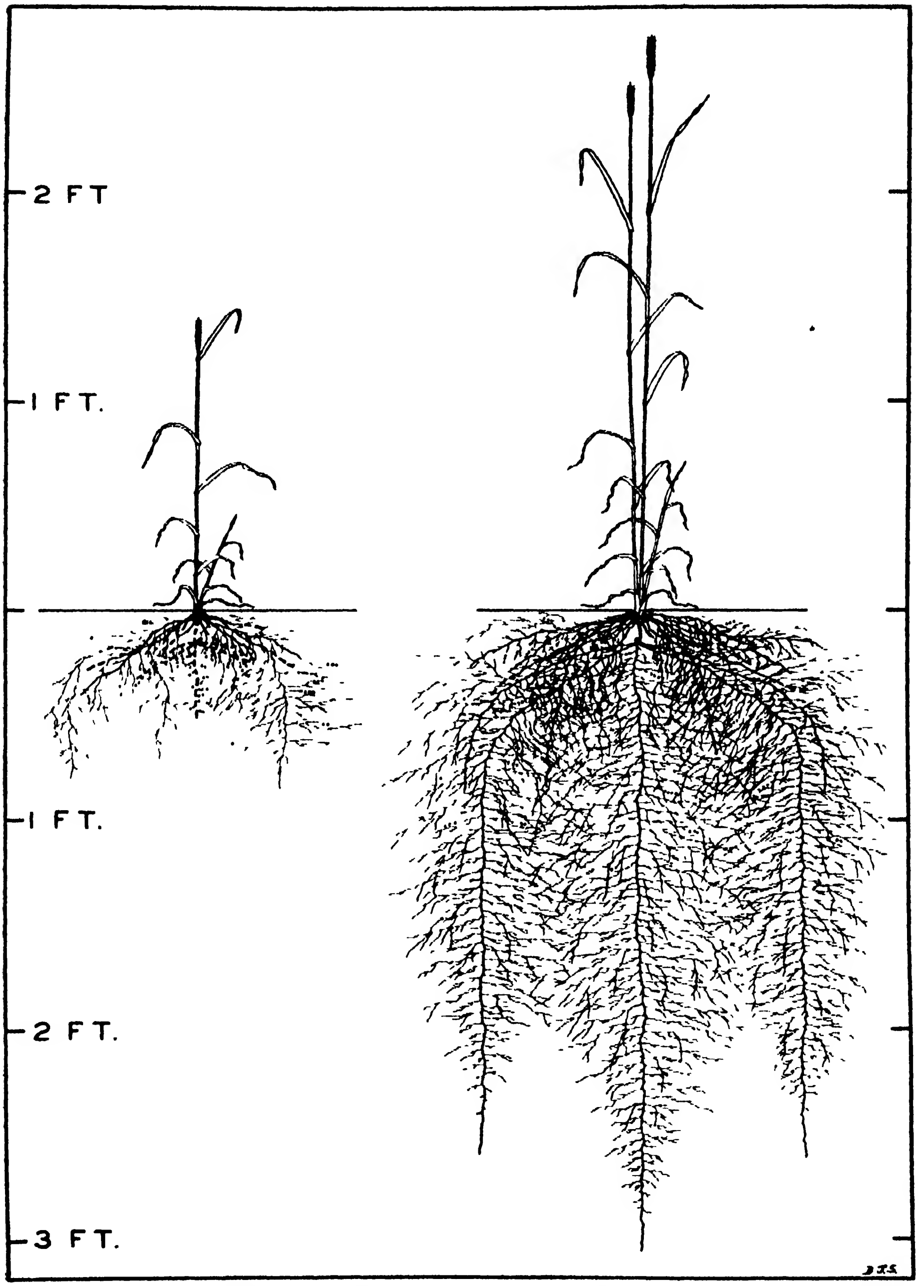

FIGURE 6. Take-all Semi-diagrammatic drawings of representative plants of Marquis wheat excavated August 9th The affected plant is represented on the left, and the healthy one on the right These illustrations are based on data contained in Table 3. The symptoms of take-all at this stage consist of blackened vestiges of the destroyed seminal roots and subcrown internode, black lesions on the crown roots, pronounced blackening of the crown and basal leaf sheaths, and premature death of the whole top. The heads may be empty or they may be poorly filled with shrunken kernels.

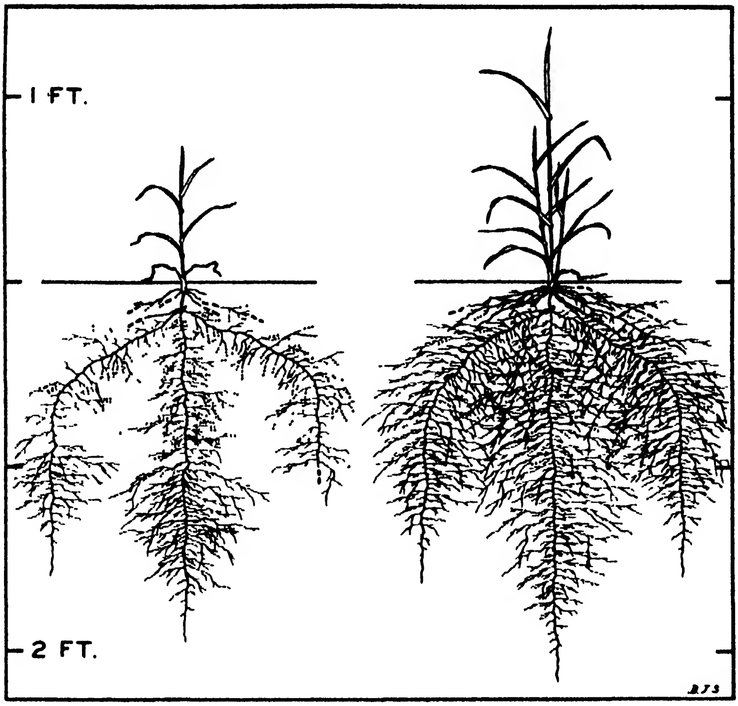

FIGURE 7. Browning root rot. Semi-diagrammatic drawings of representative seedlings of Marquis wheat excavated June 20th. The affected plant is represented on the left, and the healthy one on the right. These illustrations are based on data contained in Table 4. The symptoms of browning root rot at this stage are partially disintegrated rootlets (dotted lines), gross brown lesions at the root tips (broken lines), premature death and brownish discoloration of the leaves, and marked stunting of the whole seedling.

brownish colouring and withering of the lower leaves was a conspicuous symptom at this time of year. By midseason (Figure 8) the diseased plants had established some crown roots, in spite of the destruction of a large proportion of them, and some of the seminal roots had continued to penetrate deeper into the soil developing fresh lateral rootlets as they grew. As a result, the diseased plants had resumed growth and regained a green appearance by developing new leaves, but they were still considerably stunted. They did not possess as many tillers as the healthy plants and the development of their heads was retarded. The healthy plants reached maturity sooner than the diseased plants. The final excavations were made on the seventh of August (Figure 9). All parts of the diseased plants were decidedly stunted. Their root systems had developed very little after midseason while those of the healthy plants had developed considerably during the same period. The yield from the diseased plants was reduced to about one-fifth of that from the healthy plants.

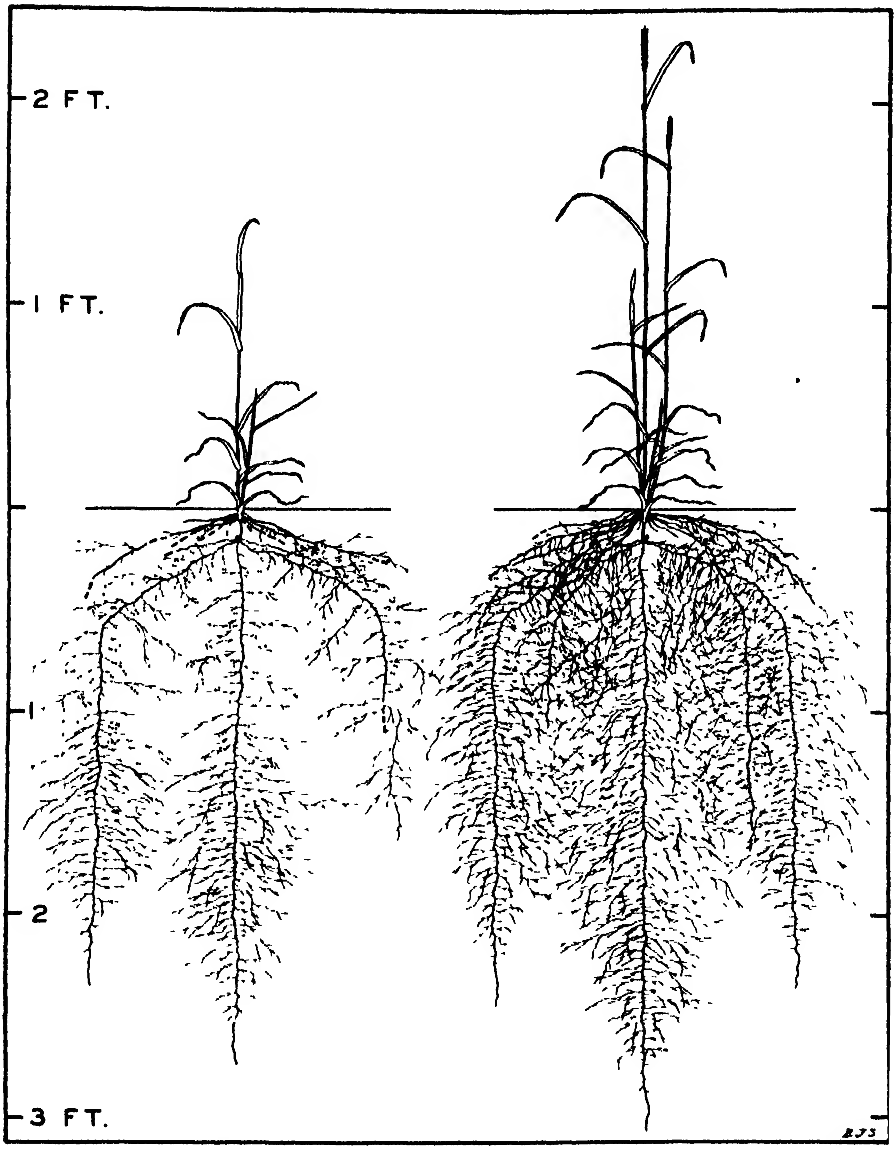

FIGURE 8. Browning root rot. Semi-diagrammatic drawings of representative plants of Marquis wheat excavated July 10th. The affected plant is represented on the left, and the healthy one on the right. These illustrations are based on data contained in Table 4. The symptoms of this disease at midseason are very similar to the symptoms exhibited in the seedling stage (Figure 7) but the plant has regained a green appearance through the production of new leaves, and gross lesions at the tips of the crown roots are more noticeable.

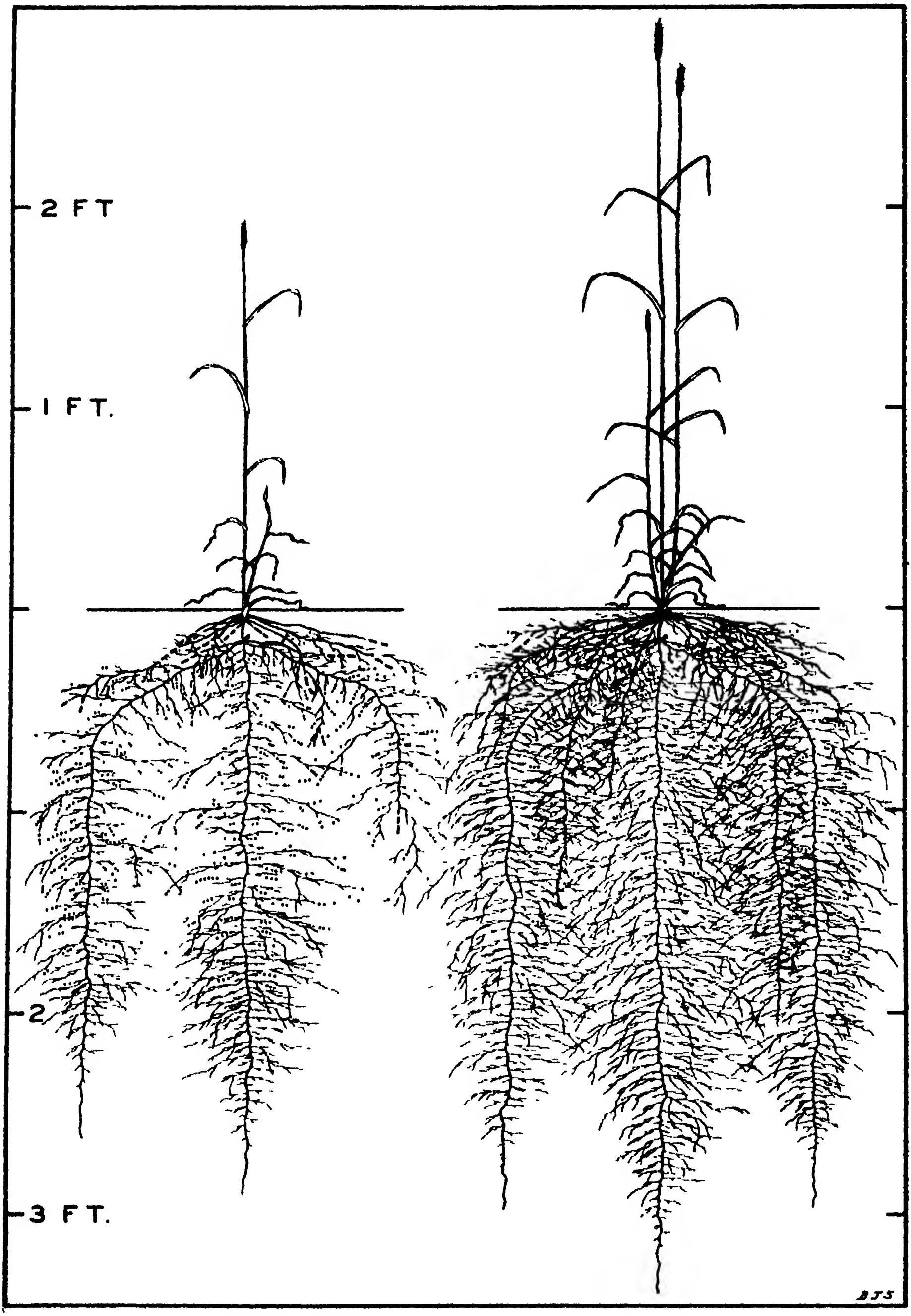

FIGURE 9. Browning root rot. Semi-diagrammatic drawings of representative plants of Marquis wheat excavated August 7th. The affected plant is represented on the left, and the healthy one on the right. These illustrations are based on data contained in Table 4. At this stage the chief symptoms of the disease are: gross lesions cutting off the crown roots, marked stunting of the whole plant, retardation of maturity, and reduction in yield.

DISCUSSION

These excavation studies show that there are characteristic differences in the time and method of attack of the three types of root rot under investigation. Common root rot, if seed-borne, is apt to blight the seedlings either before or shortly after they emerge, but if the infection arises from the soil the disease is apt to be more gradual in its development. Even in its milder forms this disease destroys some roots, both seminal and crown, and interferes with the proper functioning of others which are less severely lesioned. Also it seems probable that the deeper lesions on the subcrown internode interfere with the upward passage of water and dissolved minerals from the seminal roots and with the downward translocation of food products manufactured by the plant. Frequently root initials and tiller buds are invaded and destroyed at an early stage The action of this disease on the underground parts is clearly reflected in the top portion of the plant in the form of a stunted growth and a reduced yield of grain. Root rot is only one of the diseases produced in wheat by *H. sativum* and *Fusarium* spp., as these fungi sometimes attack the leaves and heads. The economic importance of common root rot is due largely to its ubiquity as it is present in all fields every year and may be found in any of the cereals commonly grown in this region.

The seminal roots of the host are attacked in the seedling stage by *O. graminis* and commonly they are completely destroyed. As in previous papers of this series, the seminal root system is shown to be of paramount importance to wheat grown under average field conditions in this region. Therefore, it can readily be seen that the loss of these roots seriously cripples the affected plants. Later, the disease may destroy the subcrown internode and attack the crown, crown roots and stem base just above the crown, particularly if conditions are relatively wet at midseason. The causal fungus appears to work at a depth of from one to ten inches below the surface of the soil under average conditions. If the plant is unable at any time to secure, through its impaired root systems, enough moisture from the soil to replace the water which it loses through transpiration, permanent wilting ensues and the plant dies. Other diseased plants may struggle through to maturity but the inability to get sufficient water keeps them in a more or less stunted condition, depending on environmental conditions and the extent of the injury to their root systems. As far as yields are concerned we find all gradations from plants which never come to a head to slightly affected plants which produce nearly a full normal yield.

The symptoms of browning root rot usually appear first in the early part of June. Unlike the causal organisms of common root rot and take-all, *Pythium* spp. do not produce lesions on the basal parts of the stem but confine their attack to the roots of the wheat plant. Before the crown roots emerge the causal fungi attack and destroy a large proportion of the lateral rootlets of the seminal root system. As a result, in severe cases the affected seedlings become unthrifty, most of their leaves die, starting with the lowest, and growth practically ceases for a time. However, the growing points of the older seminal roots are seldom destroyed and these continue to penetrate deeper into the soil and to form fresh lateral rootlets.

At the same time crown roots are developed and, although a large proportion of these may be cut off near the crown by severe lesions, the survivors become established and give support to the stunted seedling. Microscopic examinations of affected root systems showed that the parasite was most abundant in the top ten inches of soil although oospores were occasionally found in roots down to the 24-inch level. Wheat plants affected with browning root rot alone rarely die before maturity, under field conditions in this province, but they recover more or less rapidly and more or less completely, depending upon environmental conditions and the severity of the attack. Usually, the affected plants do not produce a normal number of tillers, they remain noticeably stunted, and their maturity is delayed. The reduction in yield of a severely diseased plant as compared with a healthy one may amount to as much as 80% but the reduction in yield from a whole field is seldom over 30%. The delay in maturity may result in a decided lowering of the quality of the yield due to rust epidemics or frosts.

To avoid confusion, we have treated the different types of root rot as though they were quite separate. As a matter of fact we frequently find that plants developing under ordinary field conditions are attacked by two or more types of root rot at one time. A striking example of such a case was found during these studies. At midseason a plant was excavated whose seminal roots had been completely destroyed by take-all, three out of four of its crown roots had been cut off by browning root rot, and lesions caused by common root rot appeared on the bases of the leaf sheaths. The plant was still living, supported by one crown root, about a foot in length, and its laterals. On the other hand one type often predominates over the other types in any one field.

The parts adjacent to the seed and the crown of the wheat plant are very vital parts from the standpoint of disease. Obviously, if the subcrown internode is destroyed at any point by a severe lesion the whole seminal root system is lost to the plant and it becomes entirely dependent on the crown roots. Take-all commonly destroys the seminal roots close to the seed and thus produces the same result. Infection about the crown may destroy tiller buds and crown root primordia while they are still in a very tender, susceptible condition and thus prevent their further development. Common root rot attacks the plant in this manner under favourable conditions. If the whole crown is destroyed the plant is certain to die. As far as we know, browning root rot does not attack the basal parts of the stem but mainly confines its attack to the laterals of the seminal roots in the upper ten inches of the soil and to the crown roots in the same soil stratum. Hence plants are rarely killed by this disease in the field.

The evidence indicates that all three types of root rot are most prevalent and destructive in the upper 10-inch layer of soil. This may be because the causal organisms find the environmental conditions much more suitable for their development in the loose top soil of high organic content than in the compact subsoil of low organic content.

Root rots undoubtedly have a marked effect upon root competition between cereals and weeds. Pavlychenko and Harrington (*3*) have shown the importance or root competition in the development of cereal crops in the presence of weeds. It has frequently been observed that weed

growth is much more vigorous in take-all patches and in fields which are severely stunted by browning root rot during the late seedling stage. Figures 1 to 9 enable one to visualize the great difference between the competition offered by a healthy wheat plant to the growth of weed roots and that offered by a wheat plant severely affected with root rot.

There appears to be a definite correlation between the proportion of the root systems which has been destroyed and the intensity of the symptoms produced by any root rot disease. Moreover, the physiologic processes of the plant may be affected by toxic substances produced when the causal organisms invade and kill the host tissues. Since light infections of any of the root rots produce only slight symptoms of disease, it is probable that root-rot damage in a mild form may frequently escape notice or be ascribed to other causes.

It has been pointed out in a previous paper (7) that the reactions of plants severely affected with root rot are comparable to the reactions of plants which have had certain of their roots amputated artificially. This is clearly the case when we compare the effects on the plant of a severe attack of take-all or browning root rot on the seminal roots, with the effects of seminal-root amputations. In each case the lower leaves of the host die prematurely, the plant becomes stunted and develops fewer tillers. If the seminal roots are amputated and a strong crown root system is developed the maturity of the plant is delayed. However, *O. graminis* commonly destroys most of the crown roots as well as the seminal roots so that maturity is hastened or the plant is killed before maturity. In cases of browning root rot, part of the seminal root system usually continues to function throughout the season and part of the crown root system is destroyed, so that although maturity may be delayed considerably the situation is not exactly comparable to the artificial amputation of the seminal roots followed by the undisturbed development of the crown root system. The similarity between the effects on the plants produced by the destruction of the crown roots by fungi and by artificial means is not so easy to discern because most cases of destruction of the crown roots by root-rot fungi are preceded by a severe infection of the seminal roots by the causal organisms.

SUMMARY

1. Three types of root rot of wheat were investigated by excavating and studying the location and extent of the injury to the root systems of affected plants in the field. Healthy plants growing under the same conditions were studied similarly for comparison. The nature of the attack from the different types of root rot varied markedly in certain respects. Accordingly, the wheat plants reacted differently, giving the several symptom complexes which are characteristic of these three types of root rot.

2. Common root rot (*Helminthosporium sativum* and *Fusarium* spp.) was characterized by brown lesions on the subcrown internodes and certain of the roots by the time the wheat had reached the late seedling stage. Both tops and roots of the diseased plants were somewhat stunted. By

midseason, lesions were more pronounced on the subcrown internodes and roots, and were present on the crowns and basal leaf sheaths as well. The roots and tops appeared quite stunted and the development of the heads was retarded. By the time the healthy plants were nearly mature severe lesions were abundant on the basal parts, particularly the subcrown internodes of the diseased plants. Both roots and tops were considerably stunted and the yield from the diseased plants amounted to only 70% of the yield from the healthy plants.

3. Take-all (*Ophiobolus graminis*) was characterized by dark brown or black lesions on the seminal roots and subcrown internodes while the wheat was still in the seedling stage. The roots and tops of the affected seedlings were stunted. By midseason, the seminal root system was almost completely destroyed, more of the subcrown internodes were blackened and lesions were noticeable on certain of the crown roots and their branches. The tops were greatly stunted and only the youngest leaves remained green. By the time the healthy plants were nearly mature the seminal roots and subcrown internodes were entirely dead. The crown roots had developed to some extent after the midseason stage but some of them and many of their branches were destroyed. The tops were almost completely bleached and consisted of one stunted culm and one dead tiller. The heads were stunted and either empty or partially filled with more or less shrunken grain. The yield from the diseased plants amounted to only 20% of the yield from the healthy plants.

4. Browning root-rot fungi (*Pythium* spp.) first attacked and destroyed many of the lateral rootlets of the seminal root system. They also invaded the growing tips of some of the later seminal roots and a large proportion of the crown roots and cut them off in the late seedling stage. As a result, the majority of the leaves died, the seedlings became markedly stunted and growth almost ceased for a period. By midseason the diseased plants had recovered to some extent, due to the continued growth of the seminal roots and of the few crown roots which escaped destruction. By the time the healthy plants were nearly mature neither the seminal roots nor the crown roots of the diseased plants had shown much further development. The tops were not only greatly stunted but the heads were greener and less mature than those of the healthy plants. The yield from the diseased plants amounted to only 20% of that from the healthy plants.

5. The damage caused by root rots to the host appears to be approximately proportional to the portion of the root systems destroyed. The reductions in yield resulting from light infections of root rot often pass unnoticed, although in the aggregate they are quite considerable.

6. From the results of previous studies of this series, as well as the results of the present study, it is believed that severe seminal-root amputations, whether caused by parasitic fungi or by mechanical means, tend to reduce the number of tillers and retard the maturity of the wheat plant. On the other hand, severe artificial amputations of the crown roots hasten the maturity of the plants. In the case of amputations brought about by parasitic fungi, however, both root systems are usually attacked and the reactions of the plants are modified accordingly.

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LITERATURE CITED

1. ANONYMOUS. Root-rots of cereals. Dom. Can. Dept. Agric Circ. No. 72. 1929.
2. McCALL, M. A. Developmental anatomy and homologies in wheat. Jour. Agric. Res *48* : 283-321. 1934.
3. PAVLYCHENKO, T. K. and HARRINGTON, J. B. Competitive efficiency of weeds and cereal crops. Can. Jour. Res. *10* . 77-94. 1934.
4. PERCIVAL, JOHN. The wheat plant. Duckworth and Co , London, Eng. 1921.
5. RUSSELL, R. C. Field studies of take-all in Saskatchewan. Sci. Agric. *10* : 654-668. 1930.
6. ——————. Studies of take-all and its causal organism, *Ophiobolus graminis* Sacc. Dom. Can. Dept. Agric. Bul. No. 170 N.S. 1934.
7. SIMMONDS, P M. and SALLANS, B J. Root amputations in the study of root-rots of cereals Proc. Can. Phytopath. Soc., pp. 33-43. 1930.
8. ——————. Further studies on amputations of wheat roots in relation to diseases of the root system Sci. Agric. *13* . 439-448. 1933.
9. ——————. Some observations on the growth of Marquis wheat with special reference to root development. Proc. World's Grain Ex. and Conf (C.S T.A , Ottawa, Can.) Vol. 2 . 263-277. 1933.
10. VANTERPOOL, T. C. and LEDINGHAM, G. A. The "browning" root-rot of cereals. Abst. Proc. Can. Phytopath. Soc., p. 13. 1930.
11. VANTERPOOL, T. C. and TRUSCOTT, J. H. L Studies of browning root rot of cereals II. Some parasitic species of *Pythium* and their relation to the disease. Can. Jour. Res. *6* : 68-93. 1932.
12. WEAVER, J. E. Root development of field crops. McGraw and Hill, New York. 1926.

Résumé

Une comparaison des différents types de pourriture de la racine du blé par l'examen des racines. P. M. Simmonds, R. C. Russell et B. J. Sallans, Laboratoire fédéral de pathologie végétale, Saskatoon, Sask.

Cette étude porte sur trois types de pourriture qui attaquent la racine du blé; le site de l'attaque et son étendue sur les racines des plantes affectées ont été notés, et des plantes saines qui poussaient dans les mêmes conditions ont été observées et comparées. Il a été constaté que la nature de l'attaque des divers types de pourriture varie beaucoup sous certains rapports, et que les plantes de blé réagissent de façon différente, produisant les différents symptômes complexes caractéristiques de ces trois types de pourriture.

La pourriture commune de la racine (Esp. *Helminthosporium sativum* et *fusarium*) se caractérisait par des lésions brunes sur les entre-nœuds sous-jacents au collet et sur certaines racines vers l'époque ou le blé touchait à la fin de la phase de plantule.

Les tiges et les racines des plantes attaquées étaient un peu rabougries. Vers la mi-saison les lésions étaient plus prononcées sur les entre-nœuds et les racines. Elles étaient présentes également sur les collets et sur les gaines des feuilles de base. Les racines et les tiges paraissaient très rabougries et le développement des épis était retardé. Vers l'époque où les plantes saines étaient à peu près mûres, les lésions graves abondaient sur les parties de la base et surtout sur les entre-nœuds des plantes malades. Racines et tiges, étaient toutes deux très rabougries et le rendement des plantes malades n'a atteint que 70 pour cent de celui des plantes saines.

Le piétin (*Ophiobolus graminis*) se caractérisait par des lésions brun foncé ou noires sur les racines séminales et les entre-nœuds sous-jacents au collet tandis que le blé était encore dans la phase de la plantule. Les racines et les tiges des plantes atteintes étaient rabougries. Vers la mi-saison, le système de racines séminales était presque complètement détruit, la plupart des entre-nœuds sous-jacents au collet étaient noircis et des lésions se remarquaient sur certaines des racines du collet et leurs branches. Les tiges étaient vitement rabougries et seules les plus jeunes feuilles étaient vertes. Vers l'époque où les plantes saines étaient à peu près mûres les racines séminales et les entre-nœuds sous-jacents au collet étaient entièrement morts. Les racines du collet s'étaient développées quelque peu après la pousse de la mi-saison, mais quelques-unes d'entre elles et beaucoup de leurs branches étaient détruites. Les tiges étaient presque complètement blanches et se composaient d'une tige centrale rabougrie et d'un rejeton mort. Les épis étaient rabougris et vides ou partiellement remplis de grains plus ou moins racornis. Le rendement des plantes malades ne se montait qu'à 20 pour cent de celui des plantes saines.

Le champignon de la pourriture brune de la racine (Esp. *Pythium*) a attaqué et détruit en premier lieu beaucoup des petites racines latérales du système de racines séminales. Il a envahi également les pointes végétatives de quelques unes des racines séminales tardives ainsi qu'une grande proportion des racines du collet et les a sectionnées vers la fin de la phase de la plantule. Il en est résulté que la majorité des feuilles sont mortes, les plantes sont devenues très rabougries et la végétation a été presque entièrement interrompue pendant quelque temps. Vers la mi-saison les plantes malades s'étaient remises quelque peu, grâce à la pousse continue des racines séminales et des quelques racines du collet qui avaient échappé à la destruction. Vers l'époque où les plantes saines étaient presque mûres, ni les racines séminales ni les racines du collet des plantes malades n'avaient pris beaucoup de développement. Non seulement les tiges étaient très rabougries mais les épis étaient plus verts et moins mûrs que ceux des plantes saines. Le rendement des plantes malades ne se montait qu'à 20 pour cent de celui des plantes saines.

Les dommages causés à l'hôte par les pourritures de la racines paraissent être à peu près en proportion de la quantité de racines détruites. Les réductions de rendement résultant d'une légère infection de la pourriture de la racine passent souvent inaperçues, quoiqu'elles soient au total très considérables.

A en juger par les résultats des études précédentes sur cette série ainsi que par les résultats de l'étude actuelle, on croit qu'une grave amputation des racines séminales, qu'elle soit causée par le champignon parasite ou par des moyens mécaniques, tend à réduire le nombre des rejetons et à retarder la maturité de la plante de blé. Par contre une grave amputation artificielle des racines du collet précipite la maturité des plantes. Cependant lorsque l'amputation est provoquée par un champignon parasitaire, les deux systèmes de racines sont légèrement attaqués et les réactions des plantes modifiées en conséquences.

LEAFY SPURGE—*EUPHORBIA ESULA* OR *VIRGATA*[1]

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[Received for publication January 26, 1935]

The weed known popularly in North America as leafy spurge has only in recent years come into special prominence, but is undoubtedly of long-standing occurrence. Both in Manitoba and in North Dakota where its weedy character has been so well demonstrated, there are records of its presence for 25 years or more, and in Minnesota evidently longer. In the east there are older records, one specimen in the National Herbarium of Canada having been collected as early as 1870 near Newburyport, R.I. That the weed should only now be creating alarm is owing probably less to any immediately changing status than to recognition at last of its insidious spread and its tenacity wherever established.

A special interest, for some of us at least, attaches to this plant by reason of recent confusion as to its specific identity. Early collections on this continent had been labelled *Euphorbia Esula* L. A related species, *E. lucida* Waldst. and Kit , was also known from a few localities in the eastern States. Our acquaintance with the first was slight, and with the other *nil*, when in 1924 a rough specimen was received from Brandon, Man., and referred, none too confidently, to the latter species. There was no evidence then at hand that either had been found so far west. The specimen was readily keyed to a choice between these two, and in view of the breadth of most of the bracts subtending the umbel, and some weighing of other points in descriptions which seemed more elaborate than enlightening, the decision was against *Esula*.

Receipt of material from other western points soon raised the issue anew. Search through European collections at the National Herbarium finally disclosed a specimen labelled *E. virgata* Waldst. and Kit., a species which was clearly not to be ignored, though not reported from America. Consultation of the best European works failing to clarify our understanding of these species, the earliest opportunity was taken to appeal to the late Dr. M. O. Malte, then Chief Botanist at the Herbarium, who arrived independently at the conclusion favoured, *i.e.*, that *virgata* was what was being dealt with. In a letter some time later he presented a translation of the characters of *Esula* and *virgata* as taken from an article by the late Prof. Ostenfeld of Copenhagen, and concluded with the statement that "all our specimens are *virgata*. We should be glad to have specimens of *Esula* should you come across it."

In the meanwhile seed of both species had been secured from various Botanic Gardens in the Old World, and roots from Manitoba, North Dakota, Minnesota, and New York, of what was being called *Esula*. From the seeds were grown some spurges not at all referable to either species, and those which were true to name (one name or the other), had not been found distinguishable when the material was discarded. The American roots were grown through a couple of seasons, were evidently of a single species, and according to our interpretation that species would be *virgata*.

[1] Contribution No. 424 from the Division of Botany, Experimental Farms Branch, Department of Agriculture, Ottawa, Canada.
[2] Botanist.

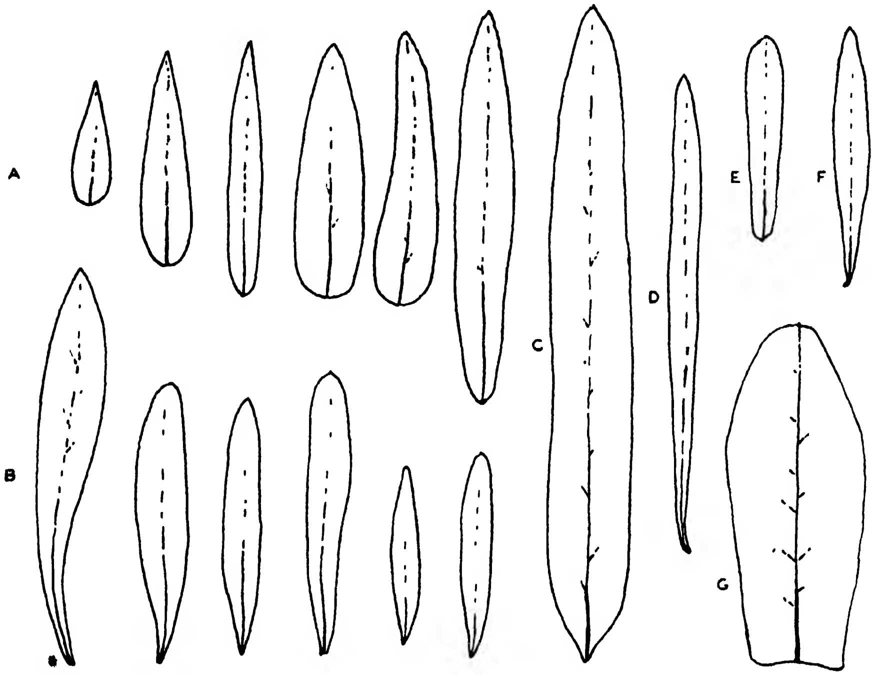

FIGURE 1. Leaf outlines of *Euphorbia* species. (Natural size.) A. *E. virgata* types. Eur. specimens. B. *E. Esula* types. Eur. specimens. C. From vigorous fruiting specimen grown in plot. D. From sterile shoot. E. Specimen with base approaching *E. virgata*, but otherwise unlike it. F. From seedling of four months. G. Broad-leaved Edgerton spurge.

On two different occasions when Dr. H. T. Güssow, Dominion Botanist, has been in Europe, he has sought further light upon the matter, and besides other help, has secured a series of specimens, presumably authentic, of the two species. Incidentally, he has put some of his botanical friends across the water to the test, and has found them not all nor always able to distinguish these far from meagrely described species.

Fine fuel for a "splitter's" and "lumper's" feud one might conclude. But after much hitherto fruitless study of our few European specimens in conjunction with our own larger series, we believe we are able at last to seize upon diagnostic characters with enough consistency for practical use. Having found them, it can be seen where they might be somewhat implied, though nowhere very clearly stated, in descriptions at hand. Unfortunately the original description of *virgata* has not been available, and may be clearer at this point than are Linnaeus' characterization of *Esula*, and later works.

In the descriptions and keys gathered from numerous sources, much has been made of the shape of the leaves, which in our experience is a character anything but constant. For instance: "We distinguish *E. Esula* from *E. virgata* by the shape of the leaves. The leaves of *virgata* are broadest below the middle—those of *Esula* are linear or broadest above the middle." (Translation from letter to Dr. Güssow from Prof. Dr. Karl

Fussengath, Munich Botanic Garden.) The concept here presented is of the whole leaf. If instead, attention were directed to the point of attachment to the stem the essential feature of the leaf shape would seem to be better stressed (See figure). In *Esula* the allegedly, but not always actually, narrower lower portion of the leaf does usually become attenuate to a little petiolate at base. In *virgata* this sometimes broader lower portion is carried through to a rounded, sessile, almost clasping base in many examples. Many leaves in this respect however, could belong to either. The actual outline depends somewhat on the breadth of the leaf, which may not be the same on all parts of the stem, and is commonly less on sterile shoots and on seedling plants. Basal leaf shape is at least a more constant and tangible feature than general outline.

Having regard then to this simple matter of leaf attachment little difficulty was found in sorting our European specimens in accordance with their labels, and then in referring the 50 or so American specimens seen (when adequate for identification), to *Esula*. In only one or two cases did a plant approximate the *virgata* type of leaf base at all closely. The European plant in the National Herbarium, moreover, which has passed as *virgata*, and in so doing helped to mislead us earlier, also conforms to this conception of *Esula*.

With this as a fresh point of departure it is proving easier to correlate other characters which alone had not been striking enough or constant enough to be very helpful. Thus, in the matter of texture, it appears that leaves of *virgata* possess a firmness, and with it a pale, somewhat olive green colour, approached sometimes by plants from the drier west, but seldom by eastern plants or those grown in the east from western material. The leaves subtending the umbel are frequently, but not always narrower in *Esula*, as commonly stated. The inflorescence appears to be more umbellate in *Esula*, and thyrsoid in *virgata*, owing to more scattered branching below the umbel and fewer rays within it, in the latter; but much depends upon the stage of development. Other criteria doubtless have value if carefully studied in enough specimens, or with the advantage of field acquaintance with both species, which we lack. Herbarium material does not indicate relative height, which is said to be greater in *virgata;* nor does it convey much idea of the root-stock, which we know is distinctly spreading in our leafy spurge, but is described as more descending in *virgata*.

In the uncertainty that has arisen, it has seemed possible that both species of *Euphorbia* were present, but it is evident that only *Esula* is represented in material studied here obtained from both east and west. *E. lucida*, referred to above, is not known apparently in Canada, but a variety of it may be here. A decidedly broad-leaved spurge (See figure), infesting a field near Edgerton, Alta., and first reported in 1933, was submitted to the Gray Herbarium, Harvard University, but lacking fully mature fruit, is still only tentatively identified as such. It has all the weedy propensities of the better known leafy spurge.

NOTE.—Since the foregoing went to press, field work near Greenstreet, north east of Lloydminster, Sask., on June 21st located a spurge which answers in all particulars which could be checked in the field to *Euphorbia virgata;* and provides strikingly in two considerable patches, field impressions of difference from *E. Esula*, which we have lacked in herbarium material.

MINERALOGICAL AND CHEMICAL STUDIES ON SOME OF THE INORGANIC PHOSPHORUS COMPOUNDS IN THE SOIL[1]

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[Received for publication February 8, 1935]

Our knowledge of the inorganic phosphates in soils includes a definite recognition of the occurrence of apatite and the assumption, with some supporting evidence, of iron phosphates the exact nature of which is in considerable doubt. The purpose of this investigation was to learn more about the inorganic phosphates occurring in soils. Commencing with the tentative hypothesis that the formation of secondary crystalline phosphate minerals might be involved in phosphorus fixation and availability, it was decided that the first objective should be the identification of such crystalline phosphate minerals as might occur in soils. The work was, therefore, largely mineralogical although some chemical studies were made.

Previous Work

A review of the literature shows that although there has been considerable speculation regarding the inorganic phosphorus compounds in the soil, little is known as regards their exact composition or properties. The only phosphorus minerals that have been identified in soils are apatite, vivianite, monazite, and turquoise. These minerals, with the exception of apatite, must be of rare occurrence since monazite and turquoise are rare phosphates, and vivianite being a ferrous phosphate could not persist in a normal, well aerated soil. The work of McCaughey and Fry (*9*), Plummer (*10*) and others shows that apatite commonly occurs. Little is known about other inorganic phosphorus compounds in the soil (*3*).

While past mineralogical researches upon soils have failed to show the presence of secondary crystalline phosphate minerals this does not mean, necessarily, that such minerals are not present, since the researches were made on the sand and coarse silt fractions, whose particles may be larger than are those of these phosphate minerals. Because no attempt beyond separating the quartz grains from the other minerals has been made in concentrating the phosphate minerals the detection and identification of such minerals would be difficult on account of the mass of other minerals present.

Recent improvements in immersion methods by Emmons (*3*) have made possible the identification of smaller mineral particles than was formerly the case. Mineral grains that are too small or too opaque to be identified by the Emmons double variation method can be identified by means of X-ray patterns if the sample is fairly pure. It seemed possible, therefore, that further information might be contributed if the phosphate minerals in the soil were sufficiently concentrated to make studies by these methods feasible.

Mechanical Separation According to Texture or Size of Grains

The soil was dispersed according to methods used in the Soils Department at Wisconsin. The soil was digested for one hour on a steam bath with normal sodium chloride solution, then filtered on a Buchner funnel

[1] This paper was constructed from a thesis submitted to the University of Wisconsin in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

[2] Lecturer of Soils.

and washed with 6% sodium chloride solution until the leachate gave no test for calcium. The excess sodium chloride was then washed out, the sample placed in distilled water and dispersed with a dispersion apparatus arranged according to Bouyoucos (*1*). Various methods were tried for the removal of the fine clay from the sample and since the sample was necessarily large and the separation was qualitative, it was found that the most satisfactory method was by settling in large vessels and decanting the suspended clay. After the removal of the fine clay the sands were easily removed by sieving.

Considerable amounts of colloidal material adhere to the silt grains even after this treatment and can only be removed by rubbing. While desirable, it is not essential that the silt grains be entirely cleaned before making specific gravity separations but it is essential that loose fine clay be removed since such material separates with difficulty.

Separation According to Specific Gravity of the Grains

The heavy liquids used in the separation of the minerals in the silt and coarse clay fraction of the soil were s-tetra-bromethane and Clerici solution, the former being used to separate the quartz, feldspar, and other minerals of specific gravity less than 2 9, and the latter to separate the minerals having a greater specific gravity. The separation was carried out by placing the sample in the heavy liquid of desired specific gravity, evacuating to remove air films around the grains and then centrifuging. This procedure will be given in more detail later.

Symmetrical tetrabromethane is a very satisfactory heavy liquid to use when a specific gravity of 2 95 or less is required. Its density is not appreciably altered by evacuating or by centrifuging, and its density can be easily lowered by the addition of nitrobenzene. Volk (*19*) has made a critical study of the use of this liquid in mineral separations.

Clerici solution was selected because it can be used successfully to make separations up to specific gravity of 4 0. This solution is prepared by dissolving equal quantities of thallium malonate ($CH_2(COOTl)_2$) and thallium formate (HCOOTl) in water. These salts may be purchased from the Eastman Kodak Company or they may be prepared according to the method reported by Vassar (*17*) or Vhay and Williamson (*18*). This solution is in some ways a convenient heavy liquid to use. Its specific gravity is easily changed by the evaporation or addition of water, it has a low thermal coefficient of expansion, and if a refractometer is available its density is easily determined since the relation between its specific gravity and refractive index is a linear one. Clerici solution has one serious disadvantage in that even slight losses of water will markedly affect its density at high gravities. The high vapor pressure of the solution makes it very difficult to prevent any loss of water during the process of separation of the minerals. The experimental results in Table 1 on following page indicate that serious errors will occur unless precautions are taken.

Another disadvantage of Clerici solution is that even a slight contamination with acids or organic liquids, such as acetone, will cause thallium salts to precipitate thus impairing if not destroying the value of the solution.

The necessity of centrifuging and evacuating has been pointed out by previous investigators. McCaughey and Fry (*9*) in 1913 mentioned the importance of the centrifuge in the separation of fine grains, and later

TABLE 1.—CHANGES IN SPECIFIC GRAVITY OF CLERICI SOLUTION DUE TO EVAPORATION OF WATER

Condition of exposure or treatment	Time of treatment	Temp. of treatment	Sp. Gr. before treatment	Sp. Gr. after treatment	Increase in Sp. Gr.
In a 150 cc. beaker, uncovered	2 hrs.	25° C.	3.17	3.31	0.14
In a 150 cc. beaker, uncovered	41 hrs.	25° C.	3.14	3.94	0.80
Centrifuging in 50 cc. tube	12 min.	25° C.	3.24	3.30	0 06
Evacuation with vacuum pump—10 cc. solution in 50 cc. tube	2 min.	25° C.	3.12	3.17	0.05

Brown (*2*) showed that quantitative results could be obtained by its use. Emmons (*3*) points out the necessity of removing the air film that adheres to each mineral particle so that the liquid can come into direct contact with it. He further reports that a good separation was obtained by evacuation alone but the writer was not able to confirm his results. To obtain best results a combination of the two methods is advisable.

The outline of the method which gave the best results with tetrabromethane and, after a few modifications, with Clerici solution follows. A small sample was placed in a centrifuge tube with the liquid of desired density, then evacuated and then centrifuged for about five minutes, running the centrifuge slowly at first and gradually increasing its speed to 1000 r.p.m. This treatment resulted in a clear-cut separation, the lighter minerals being found on the surface of the liquid and the heavier ones in the bottom of the tube. By using liquids of different densities it was thus possible to separate the sample into different minerals or groups of minerals.

Satisfactory and accurate separations were made with Clerici solution by modifying the procedure somewhat. The entire sample was evacuated in the presence of Clerici solution of the approximate density of that to be used for the separation. Further evacuation at any stage in the separation was rendered unnecessary by keeping the sample moist with the solution. The very small amount of liquid retained by the grains when transferred to a large volume of solution of slightly different density was not enough to appreciably affect the density of the liquid to which the sample had been added. Corking the tubes tightly prevented any change in specific gravity during centrifuging.

Methods of Chemical Analysis

The methods of chemical analysis employed were those regularly in use at the Soils Department of the University of Wisconsin. Wherever possible total phosphorus was determined colorimetrically by fusing the sample with sodium carbonate and extracting with water according to the method developed by Truog and Rothermel[3] and then determining the phosphorus directly by the colorimetric method as described by Truog and Meyer (*16*). The phosphorus in the acid extracts was determined volumetrically rather than colorimetrically because the large amount of ferric iron present would have interfered with the latter procedure.

[3] Unpublished work.

The combined H_2O was taken to be the loss upon ignition after drying the sample at 130° C. This method being an indirect one gives only approximately correct results.

The use of the micro-chemical test for phosphorus as described by Wiley (*20*) and others proved of much assistance in detecting the phosphorus bearing compounds with the microscope. Some phosphates are, however, so insoluble as to invalidate the test.

Four soils were studied, namely a Miami silt loam from near Madison, Wisconsin, rather low in total phosphorus; a silt loam from the limestone region of Kentucky, high in total phosphorus, hereafter called the Lexington sample; an iron rich, very acid alluvial soil from Wisconsin, high in total phosphorus; a podsol soil from central Alberta, low in total phosphorus.

Distribution of Phosphorus in Different Specific Gravity Separates

The results of the specific gravity separations and of the phosphorus analyses of the various separates for the Miami and the Lexington samples are given in Tables 2, 3 and 4. The data in Tables 2 and 3 are for the silt and coarse clay fraction, those in Table 4 for the entire soil less the fine clay and the light sand fractions. The term light is used to designate those minerals or separates having a lower specific gravity than 2.70 and the term heavy for those having a higher specific gravity than 2.70.

The data show that while in no instance was the phosphorus entirely removed from any separate it was concentrated to a much greater extent in some separates than in the others. This fact indicates that at least some of the phosphorus in these soils occurs in minerals of a definite specific gravity.

TABLE 2.—AMOUNTS OF DIFFERENT SPECIFIC GRAVITY SEPARATES IN SILT FRACTION OF MIAMI SILT LOAM AND PERCENTAGES AND AMOUNTS OF PHOSPHORUS IN THESE SEPARATES

Separate	A	B	C	D	E	F	G
Sp. Gr. range of separate	2 55–2 69	2 69–2 95	2 95–3 14	3 14–3 24	3 24–3 34	3 34–3 48	3 48–up
Amount in grams	99 3	0 71	0 32	0 28	0 28	0 62	1 24
Percent phosphorus in separate	0 011	0 068	0 038	0 063	0.10	0 038	0 240
Amount of phosphorus in mgs. in separate	10 90	0 28	0 12	0 18	0.28	0 24	2 98

TABLE 3.—AMOUNTS OF DIFFERENT SPECIFIC GRAVITY SEPARATES IN SILT FRACTION OF LEXINGTON SILT LOAM AND PERCENTAGES AND AMOUNTS OF PHOSPHORUS IN THESE SEPARATES

Separate	A	B	C	D	E	F	G
Sp. Gr. range of separate	2 56–2.70	2.70–3 16	3 16–3.38	3.38–3 52	3 52–3.66	3.66–3 91	3 91–up
Amount in grams	440	10 4	3 16	2.85	1 19	2 48	4 87
Percent phosphorus in separate	0.112	1 15	4.46	1.40	1.75	1 25	0 80
Amount of phosphorus in mgs. in separate	493	120	141	39.6	20 8	31.0	39.0

TABLE 4.—AMOUNTS OF SILT AND HEAVY SAND FRACTIONS OF LEXINGTON SILT LOAM AND PERCENTAGES AND AMOUNTS OF PHOSPHORUS IN THESE SEPARATES

Separate	1	2	3
Texture of separates	Silt	Silt	Sand
Sp. Gr. of separates	<2 7	>2 7	> 2.7
Weight of separate in grams	450	25	36
Percent phosphorus in separate	0 112	1 56	3 0
Amount phosphorus in mgs. in separate	504	390	1080

The Miami silt loam contains in the silt fraction only a small amount of heavy minerals, 97% of the sample being light minerals. The percentage of phosphorus in the heavy minerals is considerably higher than in the light minerals, but the total amount of phosphorus is much greater in the latter. An appreciable concentration of phosphorus occurs in the separate having a greater specific gravity than 3.48, this separate comprising less than 1 25% of the total sample containing about 20% of the total phosphorus in the sample.

The Lexington silt loam has a higher proportion of heavy minerals in the silt fraction. The concentration of phosphorus in the heavier minerals is many times as great as in the lighter minerals, the highest concentration occurring in the specific gravity of 3 16–3.38.

An examination of the sand fraction of the Lexington sample showed that a considerable portion was composed of dark brown to black grains which upon crushing appeared to be composed of fine particles of iron oxide cemented together. Most of these grains gave a strong test for phosphorus. Since these grains had a specific gravity greater than 2.70 they were easily separated from the remainder of the sand which consisted of quartz grains. As is shown in Table 4 this heavy sand fraction contained more phosphorus than the silt fraction. True, this coarse separate proved to be fine grained material cemented together, but in an ordinary mechanical analysis it would be classed with the sand fraction.

A partial separation of the Wisconsin alluvial soil showed that nearly all the phosphorus was present in the specific gravity separates above 3 30. These separates appeared to be composed entirely of reddish iron oxide, but analysis showed that they contained 2.7% phosphorus.

Presence of Calcium Phosphate Minerals in Soils

Microscopic examination of separate C (Sp. Gr. 3.16–3.38) of Lexington silt loam showed the presence in considerable amounts of a phosphate mineral. This mineral was, in general, isotropic but sometimes showed weak double refraction. The indices of a number of these grains as read by the Double Variation method gave an average value of 1 623 for sodium light. The general appearance of this mineral, its isotropic nature, refractive index, easy solution in acid, and the strong test it gave for phosphorus agreed with the description of the mineral collophane ($Ca_3P_2O_8$ H_2O). Direct comparison made with a museum specimen of collophane provided further proof. Rogers (*11*) states that the specific gravity of collophane ranges from 2.6–2.9. However, evidence exists that Rogers is too low in his upper limit. A specific gravity determination on a sample of collophane obtained from Rogers showed that more than half the

sample had a specific gravity greater than 2.9. Also a recent paper by Martens (*8*) points out that most of the collophane he was working with sank readily in a liquid with a density of 2.85.

Collophane was found in separate B of the Lexington sample but it was not found in any of the separates whose specific gravities were greater than 3.38. No other calcium phosphate minerals were found in this soil.

There is little doubt but that the collophane in the Lexington soil is a residual mineral left from the weathering of the parent limestone rock. Calcium phosphates are supposed to weather quite rapidly but because of the abundance of collophane in this soil it would seem that at least certain varieties are fairly resistant. The mineral apatite ($Ca_5(F, Cl) P_3O_{12}$) is also supposed to be easily soluble and yet it has been found in many soils. A study of the leached layer (7) of an Alberta podsol showed the presence of fresh grains of apatite which indicates that certain apatites can resist even severe weathering for a considerable time. McCaughey and Fry (*9*) noted that the apatite found in soils was invariably the fluor variety and by analogy it would seem that the collophane found in soils may be the fluor collophane.

Presence of Iron Phosphates in Soils

Micro-chemical examination indicated that there were at least two phosphorus compounds in the heavier specific gravity separates of these soils, one readily soluble in acid solution and one comparatively insoluble. Both of these phosphorus compounds were in brown to black opaque grains which did not exhibit any crystalline properties. Since such compounds could not be identified with the microscope, it was necessary to resort to X-ray and chemical propeities.

A study of the Lexington separate 3 (see Table 4) and the heavier separates of the Wisconsin alluvial soil showed that both these phosphorus compounds were present Since there were much more of these separates available than of any of the other separates containing these compounds, further study was confined to them.

Efforts to concentrate the phosphorus bearing compounds in separate 3 of the Lexington soil by specific gravity separations resulted in failure. Even after the removal of the easily soluble phosphorus compound no concentration could be obtained as Table 5 shows.

TABLE 5—PHOSPHORUS CONTENT OF THE HEAVY SPECIFIC GRAVITY SEPARATES OF LEXINGTON SAND AFTER TREATMENT WITH 1 PER CENT (BY VOLUME) SULPHURIC ACID

Separate	1	2	3	4	5	6
Range in Sp. Gr.	3.1–3.41	3.41–3.50	3.50–3.66	3.66–3.75	3.75–4	4–up
Per cent phosphorus	1.25	1.25	1.25	1.25	1.25	1.12

The even distribution of the phosphorus throughout indicated that the phosphorus compound or compounds were present in intimate association with other grains and were not present as discrete grains or crystals.

Each of the above separates and a sample of the untreated material was X-rayed. The results showed that the only crystalline substance

present in any of the separates was quartz. This meant that the other compounds present were amorphous. The reason quartz was found in this separate may be due to its presence as tiny crystals that were coated with so much iron oxide that as regards specific gravity deportment they did not behave according to their own specific gravity.

No attempts were made to further concentrate the heavy separate of the Wisconsin alluvial soil, as nearly all the grains gave a strong test for phosphorus. No crystalline minerals could be detected and X-ray analysis showed that this material was amorphous.

Solubility of the Iron Phosphates in Soils

It has previously been pointed out that the fundamental thesis of this investigation was to discover and identify the crystalline phosphate minerals in the soil. However, after the failure to find any crystalline minerals in the iron rich high phosphorus separates of three soils it was thought well to digress from this thesis and to endeavor to find by chemical methods the composition of the phosphates present in these separates.

A fairly complete total analysis was made of the Lexington separate after treating with 1% sulphuric acid to remove the easily soluble phosphorus compounds. This was done in order to determine the possible bases with which the phosphorus might be in combination. The analyses showed that the phosphorus must be in combination with iron or aluminum, as no other base was found to be present. The presence of quartz as shown by the X-ray analysis previously mentioned was verified by the analyses.

When the Lexington sample was treated with 1% sulphuric acid a considerable amount of iron was brought into solution. Tests were made on a number of iron oxides to determine their solubility in acid treatments. Hematite, Turgite, Goethite, and limonite were slightly soluble at 86° C. but at 26° they were practically insoluble except some samples of limonite which were partly soluble in all strengths of sulphuric acid from 1 to 20%. The fact that some limonites were partly soluble while others were not was a puzzling one until it was discovered that phosphorus was always present in the extracts from the soluble ones. The conclusion was drawn that pure limonite is practically insoluble in cold acid and that any appreciable solubility is due to the presence of soluble iron phosphates. Roscoe and Schorlemmer (*12*) point out that basic iron phosphates occur in nature frequently as a constituent of limonite. It appears safe to assume as a result of this work that practically all the iron dissolved by the acid extractions of the heavy separate was in combination with phosphorus.

Samples of the Lexington heavy separate 3 (Table 4), limonite that showed soluble iron, and the heavy separate of the Wisconsin alluvial soil, were treated with different strengths of sulphuric acid at room temperature (25° C.). The relative amounts of Fe_2O_3, Al_2O_3, P_2O_5 and combined water extracted from these samples by this treatment, expressed on the basis of P_2O_5 equals 100, are shown in Table 6. Analysis of the residue showed that all the phosphorus was extracted from the alluvial sample but only about half of it from the Lexington sample. The limonite residue was not analyzed.

TABLE 6.—ANALYSES OF SULPHURIC ACID EXTRACTS OF LEXINGTON HEAVY SAND FRACTION, LIMONITE, AND HEAVY FRACTION OF WISCONSIN ALLUVIAL SOIL

Expressed as comparative weights —P_2O_5 = 100

Sample	Lexington	Limonite	Wisconsin alluvial
Time of treatment	24 hrs	24 hrs	2 hrs
Strength of acid	1% by vol	1% by vol	5% by vol
Fe_2O_3	289	441	800
Al_2O_3	136	None	None
P_2O_5	100	100	100
H_2O	164	128	205

The data in Table 6 show that phosphorus is combined with iron and possibly aluminum, forming highly hydrated phosphates. The iron extracted from the treated samples was all in the ferric state.

Assuming in the case of the Lexington separate that the aluminum as well as the iron is in combination with the phosphorus, although it may have come from other aluminum compounds in this separate as the solubility of such compounds with this treatment is not known, a compilation of the analyses of the acid extracts gives the molecular ratio of the oxides believed to be in combination with the phosphorus as follows:

Lexington separate—1% acid	$4.5R_2O_3.P_2O_5.13H_2O$
Limonite sample—1% acid	$4Fe_2O_3.P_2O_5.10H_2O$
Wisconsin alluvial separate—5% acid	$7Fe_2O_3.P_2O_5.16H_2O$

From the above ratios and the fact that all the phosphorus was extracted by 5% acid, but only about half by 1% acid, it would seem that the more basic the phosphate the more insoluble it is.

C. W. Stoddart (*15*) stated that it is commonly assumed that the iron phosphate mineral in soils is the basic iron phosphate Dufrenite ($Fe_2(OH)_3 PO_4$). The investigations reported in this paper have been limited in number and in scope but from the results so far obtained this assumption is not substantiated. The evidence shows that crystalline iron phosphates are not formed in soils and that the iron phosphates found there are more basic than any phosphorus mineral so far reported.

Russell (*14*) points out that it is remarkable that X-ray analyses of colloidal clay have failed to show the presence of limonite or hematite. The investigations reported in this paper show that the iron oxides present in soils are amorphous.

SUMMARY

Some of the phosphates in several soils were studied by mineralogical and chemical methods. A mineralogical method adopted for the concentration of inorganic soil phosphates, based on specific gravity separation did not result in the complete isolation of such phosphates but appears to be the best means of accomplishing their concentration. The use of the petrographic microscope in identifying soil phosphates is limited because the secondary phosphates appear to be amorphous. The phosphorus of the soil is not confined to any particular specific gravity portion. It is, however, concentrated to a large extent in the heavy fractions and more particularly in certain portions of these fractions.

The calcium phosphate minerals apatite and collophane were found in relative abundance in a certain few soils. They are believed to be

primary minerals; that is, they have not been formed in the soil. The secondary phosphates of iron and aluminum found in the soils studied are amorphous. Such phosphates have a complex chemical composition and are highly hydrated. Iron oxides found in the soil were also amorphous.

REFERENCES

1. Bouycoucos, G. J. The hydrometer as a new and rapid method for determining the colloidal content of soils. Soil Sci. *23* : 319-331. 1927.
2. Brown, Irvin C. A method for the separation of heavy minerals of fine soil. Jour. of Paleontology *3* : 412-414. 1929.
3. Emmons, R. C. The double variation method of refractive index determination. Am. Min. 14, 11, 414-426. 1929.
4. —————. On gravity separations. Am Min *15* : 536. 1930.
5. Failger, G. H., Smith, J. G. and Wade, H R. The mineral composition of the soil particles. U.S.D.A., Bur. of Soils, Bul. 54.
6. Fry, W. H. The condition of the phosphoric acid insoluble in HCl. Jour. Ind. Eng. Chem., *5* : 662. 1913.
7. Leahey, A. Leaching of mineral matter in some Alberta soils. Sci. Agr., *13* : 7-15. 1932.
8. Martens, J. C. Detrital collophane. Am. Min. *17* : 153-155. 1932.
9. McCaughey, W J. and Fry, W. H. The microscopic determination of soil forming minerals. U S D.A. Bur. of Soils, Bul. 91 1913.
10. Plummer, J. K. The petrography of some North Carolina soils. Jour. Agric. Res., *5* : 569-581. 1915-16.
11. Rogers, A. F. Collophane—a much neglected mineral. Am. Jour. Sci. 5 ser. *3* : 269-276. 1922.
12. Roscoe, H. E. and Schorlemmer, C. Treatise on Chemistry. *2* : 1017. Pub. by D. Appleton and Co., N.Y. 1897.
13. Russell, E. J Soil conditions and plant growth. 6 ed. p. 238. Longmans, Green and Co., New York. 1932
14. ——————————————. p. 172.
15. Stoddart, C. W. Soil acidity in its relation to lack of available phosphorus. Jour. Ind. Eng. Chem , Vol. 1. 1909.
16. Truog, E and Meyer, A. H. Improvements in the Deniges colorimetric method for phosphorus and arsenic Ind Eng Chem., *1* · 136 1929
17. Vassar, H. E. Clerici solution. Am. Min , *10* . 123-125. 1925.
18. Vhay, J. S. and Williamson, A. T. The preparation of Thallous Formate. Am. Min , *17* · 560-563. 1932
19. Volk, N. J. The formation of muscovite in soils and refinements in specific gravity separations of minerals. Am Jour. Sci , *26* . 114-129. 1933.
20. Wiley, H W Principles and practice of agricultural nalysis. *1* . 293-294. Chemical Publishing Co , Easton, Pa. 1908.

Résumé

Etudes minéralogiques et chimiques de quelques-uns des composés inorganiques de phosphore dans le sol. A. Leahey, Université de l'Alberta, Edmonton, Alberta.

Quelques-uns des phosphates dans plusieurs sols différents ont été étudiés au moyen de procédés minéralogiques et chimiques. Un procédé minéralogique adopté pour la concentration des phosphates inorganiques du sol, basé sur la séparation par pesanteur spécifique, n'a pas réussi à isoler complètement ces phosphates, mais il semble que ce soit le meilleur moyen de réaliser leur concentration. L'emploi du microscope pétrographique pour identifier les phosphates du sol est limité, parce que les phosphates secondaires paraissent être amorphes. Le phosphore du sol n'est pas limité à une portion spéciale de pesanteur spécifique, mais il est concentré dans une large mesure dans les fractions lourdes et spécialement dans certaines parties de ces fractions. Les minéraux de phosphate de calcium, apatite et collophane, ont été trouvés en abondance relative dans certains sols. On croit que ce sont des minéraux d'origine primaire, c'est-à-dire qu'ils ne se sont pas formés dans la terre. Les phosphates secondaires de fer et d'aluminium trouvés dans les sols étudiés sont amorphes. Ces phosphates ont une composition chimique complexe et sont fortement hydratés. Les oxydes de fer trouvés dans le sol étaient également amorphes.

THE ECONOMIC ANNALIST

A REVIEW OF AGRICULTURAL BUSINESS PREPARED QUARTERLY BY THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA

Vol. V, No. 2. June, 1935

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index of wholesale prices in Canada advanced from 72 0 in March to 72.5 in April. The vegetable products index rose from 67.5 to 69 4. Non-ferrous metals and their products showed a similar gain from 65 2 to 67 9. There was also a slight advance in the index of prices of wood, wood products and paper. These three factors more than offset losses in other groups and resulted in a rise of a half point in the total index.

Wholesale price levels in other countries within the sterling and gold "blocs" declined moderately during the first quarter of 1935 according to a statement recently issued by the Internal Trade Branch of the Dominion Bureau of Statistics.

Retail prices in Canada were slightly lower than in March, the index receding to 78.8 because of a decline in retail prices of foods.

Physical Volume of Business.--The index of the physical volume of business regained much of the loss recorded in March, the April index being 98 3 compared with 94 2 in the previous month. Industrial production was also higher in April, rising to 97 7. Mineral production advanced from 143 4 to 156 4. Exports of nickel were lower but shipments of gold, silver and copper were substantially higher. There was also a marked increase in the production of lead.

In the manufacturing group increased activity was quite marked and the index rose from 86 8 in March to 94 0 in April. Flour production advanced from 72.5 to 82 6 Manufacture of sugar, exports of cheese and canned salmon were well above the volume reported in March.

The forestry index also showed a gain largely because of increased exports of newsprint, wood pulp and shingles. The index of iron and steel production showed a moderate gain, rising from 90 2 to 92 2. Automobile production was slightly below the peak recorded in March. Construction continues at very low levels, the April index being below that for March. Car loadings showed a slight gain. Both exports and imports were higher than in the previous month. The index of grain and live stock marketings advanced from 65 4 to 91.8. Grain marketings were substantially higher but shipments of live stock were lower. Cold storage holdings fell from 143 2 to 135 8.

Agricultural Products.—The index of wholesale prices of Canadian farm products rose from 62.7 to 64 7. This gain was due to improvement in the prices of field products which index advanced from 56 4 to 59 8. The average price of No. 1 Manitoba northern wheat was 87.6 cents per bushel in April, basis Fort William and Port Arthur compared with 81 9 cents in March. Prices of barley, oats, rye and flax were also higher. Moisture conditions are much more satisfactory in Western Canada than a year ago but cold weather has delayed seeding and retarded growth in all sections of the country.

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1934	71.6	59.0	53.9	67.6	78.9	94.2	93.6	88.5	114.2
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.8
Nov.	71.2	61.2	55.7	70.4	79.4	96.5	97.0	51.2	130.4
Dec.	71.2	61.6	56.0	70.9	79.0	92.4	91.0	36.0	135.7
1935									
Jan.	71.5	61.4	55.7	71.0	78.9	97.5	97.8	30.6	143.7
Feb.	71.9	62.0	55.7	72.6	79.1	100.6	101.1	62.2	141.2
Mar.	72.0	62.7	56.4	73.3	79.0	94.2	93.3	65.4	143.2
Apr.	72.5	64.7	59.8	72.9	78.8	98.3	97.7	91.8	135.8

1 See Prices and Price Indexes 1913-1928, pp 19-21, 270-289 and 1913-1932, p 15

2. Wholesale prices of Canadian products of farm origin only See Prices and Price Indexes 1913-1932, p. 32, and Monthly Mimeographs 1933 and 1934

3 Wholesale prices of grains, fruits and vegetables

4 Wholesale prices of Animals and Animal Products

5. Including foods, rents, fuel, clothing and sundries, See Prices and Price Indexes 1913-1928, pp 181-185, 290-293 1926 = 100
Prices and Price Indexes 1913-1931, p 122, and Monthly Mimeographs, 1933-1934

6 Monthly Review of Business Statistics, p 8, and Monthly Indexes of the Physical Volume of Business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

The report on farmers' intentions to plant issued by the Agricultural Branch of the Dominion Bureau of Statistics indicates that there will be a reduction of 3% in the acreage of spring wheat in 1935. This is the third successive year in which a reduction has been reported but it is not as large as in 1933 or 1934. Most of the

reduction is in Saskatchewan where it amounts to 4%. On the other hand, intended acreage of oats will be 4% higher and that of barley will be 5% larger than in 1934. Farmers' intentions to plant potatoes indicate a reduction of 8% chiefly in the Maritime Provinces.

The index of prices of animal products receded from 73.3 to 72.9. Prices of eggs and calves were lower. Cattle prices were higher early in the month but were lower towards the end, reflecting conditions in United States markets. Hog prices advanced throughout April, and lambs sold at better prices on all markets except Toronto where heavy receipts from Western Canada were responsible for a recession.

Exports of cattle to United States to May 16 were 63,893 head. Sales of cattle at public markets to the foregoing date were 359,983 head compared with 415,212 head during the same period in 1934. Sales of calves were 133,969 and 313,644 respectively. Shipments of sheep were 76,116 and 70,900 during the same periods and hog gradings 1,236,768 in the first twenty weeks of 1935 against 1,286,060 during the first twenty weeks of 1934. Exports of bacon and hams to the United Kingdom during the twelve months ending March 31, 1935, were 1,270,529 hundredweight, compared with 945,597 hundredweight in the year ending March 31, 1934.

Production of butter during the first three months of 1935 compared with the same period in 1934 showed a decrease of 8.8%. The most marked regional decline took place in the Maritime Provinces. In Quebec on the other hand, there was an increase of 3.5%. British Columbia had an increase of 1.9%. There were decreases of 15.8 and 14.0% in Saskatchewan and Alberta, and Ontario showed a decrease of 5.8%. Total output was 23,660,171 pounds compared with 25,932,258 pounds in the first three months of 1934.

There was a slight increase in the number of boxes of cheese graded during the period December 3, 1934, to April 27, 1935, the total being 44,007 compared with 41,904 during a similar period ending April 28, 1934.

FARM ASSESSMENT IN QUEBEC[1]

S. C. Hudson[2]

Since taxes in rural municipalities are, for the most part, levied on the basis of real property, the major responsibility for an equitable distribution of the burden of municipal taxation rests with the assessors who evaluate the holdings of the individual taxpayer. Although such taxes are levied on real estate rather than income, it should be remembered that they must be paid in the long run, if at all, from income. The assessment of the farm then, if it is to be satisfactory, must reflect the productive capacity of that farm as measured by farm income.

The relation of farm taxes to farm income on a number of farms in the Province of Quebec is presented in Table 1. In this table, records of some 84 farms businesses were sorted on the basis of farm income and the farm taxes expressed as a percentage of the farm income for each group. The fact that farmers having incomes of less than $1,000 paid over 33% of their incomes in taxes, while those having incomes of $3,000 or more paid less than 3% of their incomes to their municipalities indicates that under the existing system, farmers with low incomes are taxed more heavily than those with large incomes. While it may be that some farmers received low incomes due to misfortune or poor management, it would seem that further study of assessment and factors affecting its accuracy would be helpful.

In an attempt to study the accuracy of the assessment of individual farms in a number of rural municipalities in Quebec, the assessed valuations of 84 farms for which farm management records were available were obtained from the respective

[1] This study was conducted in co-operation with the Department of Farm Economics, Macdonald College, P.Q., and is a preliminary statement subject to revision and correction.
[2] Field Assistant, Economics Branch, Department of Agriculture, Ottawa.

TABLE 1.—RELATION OF FARM INCOME TO FARM TAXES ON 84 QUEBEC FARMS

Farm income	Number of farms	Farm taxes in per cent of farm income
$		
Minus income	19	--
0–1,000	37	23 5
1,000–2,000	16	11 5
2,000–3,000	8	5 4
3,000 and over	4	2 9
Totals	84	13 8

municipal clerks and compared with the farm value as estimated by the farm operator in collaboration with an experienced farm management investigator. A frequency distribution of these farms according to the ratio of assessed to estimated value is presented in Table 2. While considerable variation may be noted in the assessment practices in different municipalities, the average assessment ratio varying from about 20 to 60% of the estimated value, the variation in the assessment ratios of individual farms within each municipality is of much greater consequence.

The results of this variation in assessment may be noted in Table 3 in which the farms are grouped according to their estimated value. While farms valued under $1,000 were assessed on the average at 48 2% of their estimated value, those valued at from $10,000 up to $20,000 had an average assessment ratio of 37.7% and those valued at $20,000 and over were assessed at 30 1%. That is, low-valued farms are over-assessed and thus over-taxed relative to those of higher value.

TABLE 2.—FREQUENCY DISTRIBUTION OF SOME QUEBEC FARMS ON THE BASIS OF THE RATIO OF ASSESSED TO ESTIMATED VALUATION

Class interval	Twp. No. 1	Twp No. 2	Twp. No. 3	Twp. No. 4	Twp. No. 5	Twp. No. 6	Totals
5– 10	–	1	–	–	–	–	1
10– 15	–	–	–	–	–	–	–
15– 20	1	6	–	–	–	–	7
20– 25	2	6	–	–	–	–	8
25– 30	1	4	–	1	–	–	6
30– 35	9	2	–	4	–	–	15
35– 40	3	–	2	1	1	2	9
40– 45	2	–	2	1	2	3	10
45– 50	–	–	1	1	–	1	3
50– 55	4	–	–	1	1	–	6
55– 60	–	–	1	–	–	–	1
60– 65	–	–	–	2	3	2	7
65– 70	–	1	2	–	–	–	3
70– 75	–	–	1	1	–	–	2
75– 80	–	–	–	–	–	–	–
80– 85	–	–	2	–	–	–	2
85– 90	–	–	–	–	1	–	1
90– 95	–	–	–	–	–	–	–
95–100	–	–	–	–	–	–	–
100–105	–	–	2	–	–	–	2
105–110	–	–	–	1	–	–	1
Totals	22	20	13	13	8	8	84
Average ratio	33 1	20.4	60.1	44 3	53 7	46.9	36.8

In order to determine the reason for this tendency on the part of assessors to over-value farms in the low value groups as compared with those in the higher limits, a study was made of the extent to which certain factors affecting the value of property are considered by assessors. Factors studied included size of farm, value per arpent, and the relative value of buildings.

In considering the relation of size of farm to accuracy of assessment, it was found that farms of different size were assessed at substantially the same percentage of their estimated value (Table 4).

TABLE 3. —RELATION OF VALUE OF FARM TO EQUALITY OF ASSESSMENT

Value of farm	Number of farms	Average ratio of assessed to estimated value
$		
0-10,000	42	48 2
10,000–20,000	23	37 7
20,000 and over	19	30 1
All farms	84	36 8

TABLE 4. RELATION OF SIZE OF FARMS TO EQUALITY OF ASSESSMENT

Size of farm (arpents)	Number of farms	Average ratio of assessed to estimated value
Under 100	36	37 3
100 – 200	33	36 0
200 and over	15	37 3
All farms	84	36 8

A study of the relation of the "per arpent" value of farm property to the accuracy of assessment, however, indicates that while farms valued at less than $100 per arpent are assessed on the average at over 48% of their estimated value, those valued at $150 or over were assessed at 32% (Table (5). That is, farms having a low "per arpent" value are over-assessed as compared with those having a high "per arpent" value due to the fact that the assessor apparently does not give sufficient consideration to the "quality" aspect of a farm in making his assessment. As a result of this, a highly productive farm is often assessed at a lower percentage of its full value than one the productivity of which is relatively low.

The influence of the relative value of buildings and improvements on the accuracy of assessment is presented in Table 6. While farms on which buildings made up less than 20% of the value of the farm were assessed at 29% of their estimated value, those on which buildings accounted for over 60% of the value of real estate had an assessment ratio of 48%. In appraising a farm, therefore, the assessor apparently gives undue weight to buildings with the result that a poor farm which is well equipped in this respect may be assessed much higher than a more productive one, having less pretentious buildings

TABLE 5. —RELATION OF THE "PER ARPENT" VALUE OF REAL ESTATE TO EQUALITY OF ASSESSMENT

Estimated value of real estate per arpent	Number of farms	Average ratio of assessed to estimated value
$		
Under 100	36	48 2
100 – 150	11	35 9
150 and over	37	32 1
All farms	84	36 8

TABLE 6.—RELATION OF THE PROPORTION WHICH VALUE OF BUILDINGS IS OF VALUE OF REAL ESTATE TO EQUALITY OF ASSESSMENT

Value of buildings expressed as a percentage of value of real estate	Number of farms	Average ratio of assessed to estimated value
Under 20	7	29 0
20 – 40	38	38 3
40 – 60	32	36 4
60 and over	7	48 4
All farms	84	36 8

From the foregoing, it is evident that considerable inaccuracy exists in the assessment of farm property in the Province of Quebec with the result that low-valued farms are over-assessed relative to those of higher value. Two of the principal causes of this inaccuracy of assessment were found to be the tendency on the part of the assessor to give insufficient consideration to the "quality" aspect of a farm and to place undue emphasis on the presence of buildings in appraising a farm for assessment purposes. A similar tendency was found to exist in the Province of Ontario.

AGRICULTURAL MARKETING RESEARCH

W. C. HOPPER[1]

One of the primary objects of agricultural marketing research is to obtain facts concerning demand which will lead to increased returns to producers of agricultural commodities. Another is to obtain information which will reveal methods of reducing the spread between producer and consumer prices.

In recent years much emphasis has been placed on the need for better and cheaper methods of distribution but before much can be accomplished in their improvement, facts respecting present distribution methods and costs must be obtained, tabulated and analysed. There are different ways of approaching a study of marketing agricultural products One of these is the commodity approach. The marketing problems of farmers, however, vary not only with the commodity but also with distance from market, facilities for marketing and methods of marketing. The marketing problems of the farmer in Northern Ontario, for example, are quite different from those of the wheat farmer of the Prairies, the potato farmer in the Maritime Provinces and the fruit grower of Ontario and British Columbia.

Many farmers who, formerly, were interested primarily in production are beginning to realize that the demand for the product which they have to sell is as important in determining the price as the supply of that product.

A comprehensive study of the marketing of any particular commodity would involve the gathering of information of the whole process of distribution of that product from the producer to the consumer. Such a study would include investigation with respect to the methods and practices of those engaged in marketing, the costs of preparation and transportation, the facilities for handling at the farm, at the country point and at the terminal, auction or public market, wholesaling and retailing costs and the many aspects of the demand or preferences of the ultimate consumer. Such a comprehensive investigation might also include a study of the relations of quality or grade to the price obtained by the producer, the country buyer, the wholesaler and the retailer.

There are certain more or less basic agricultural products produced in Canada which are as good or better in quality than similar products produced in other countries There are certain agricultural products which, because of the suitability of the Canadian climate and soil are produced at a lower cost than similar products can be produced in other countries. Amongst these products might be included apples, potatoes, bacon, cheese, wheat, barley, poultry products, alfalfa seed, and so forth. While the major part of our farm products are consumed at home and it is domestic marketing that requires the most intensive study, nevertheless, a study of the demand for such commodities in countries other than Canada should be of distinct advantage to the Canadian producer as well as to the nation as a whole That portion of the product which is exported may determine the price for all the product sold at home and abroad. In the nature of *definite marketing research*, very little study has been devoted to the obtaining of facts on consumer preferences and competition with other commodities in overseas markets with a view to expanding the sale of our export products in countries which now use but small quantities of these commodities.

Reducing the Cost of Marketing.—Efforts to decrease the costs of marketing and reduce the spread between consumer and the producer prices so that farmers may obtain a larger share of the consumer's dollar, cannot be very successful without a knowledge of the existing marketing costs.

One of the largest items in the costs of getting farm products to market is that of transportation. The use of the motor-truck has in recent years helped to reduce the cost of transporting certain farm commodities to market. Very little study, however, has been given to cost of operating motor-trucks. Farmers sometimes wonder if it will pay them to purchase a motor-truck or to have the product which they have to

[1]Chief Division of Marketing, Economics Branch, Department of Agriculture, Ottawa.

market, handled by hired truckers. Little is known about the fairness of the rates charged by truckers and little has been done to regulate the movement of farm products by trucks in order to avoid market "gluts" and "famines." Many of our present marketing facilities are uneconomic and inadequate. With the rapid growth of motor-truck distribution, facilities for handling farm produce in our cities have not been developed to meet the needs of this new method of transportation. New methods of retailing farm products in the city and at the roadside have come about in recent years. These changes in transportation and in methods of handling farm products should be studied with a view to modernizing marketing facilities in order to reduce marketing costs When farm prices fall, marketing costs tend to remain high, and a wide margin between the producer and the consumer prices exists. In many cases inefficiency in the marketing system rather than excessive profits in distribution are the cause of these wide margins Studies relating to the costs of grading, packaging, processing, handling, storing, wholesaling and retailing farm commodities should reveal facts which would aid in promoting more efficient marketing.

Studies of Consumer Demand.—Recognizing that the ultimate end of all production is consumption leads to the conclusion that studies of the many aspects of consumer demand for any particular commodity at home and abroad will reveal ways of increasing consumer demand for that commodity. Studies of the demand of consumers with different incomes, of different nationalities and in different locations with respect to the quality, grade, size and other characteristics of the commodity and of the uses made of that commodity in different households, should help farmers to decide the kind of product to produce if they wish to meet the needs of the consumers. Studies relating to the style and size of the package in which the commodity is marketed and the methods of retailing which will reach the largest number of consumers, should help farmers to decide how they should market the commodity. A knowledge of the kind of product which meets the desires of the majority of consumers and the marketing of that product in the manner best adapted to the need of the buyers are of greatest importance to producers of every class of commodity, whether the producer be a farmer, gardener, fruit grower, poultryman, publisher, builder or manufacturer

Producers of many kinds of manufactured products are finding it to their advantage to make a careful study of the use by the consumers of the commodity they sell. An interesting example of the use of marketing research in business is given in the book entitled Marketing Research Technique by Percival White. The author states that important decisions in business are surprisingly easy to make if all the facts are known. The Parker Pen Company believed that the public would purchase coloured fountain pens and also large-sized pens Should such pens be produced and offered to the public? If a wrong decision were made, the results might be very costly. Users of fountain pens were approached for information on the subject and the consensus of the opinion was that coloured and large-sized pens were desirable and would be saleable. A comparatively small number of such pens were then made for use in trial markets. As these experimental sales were successful, widespread distribution was then attempted. The result was very satisfactory. The Company, however, might have been wrong in its original belief, and if it had not first used field research and trial sales, might have plunged into a disastrous attempt to give the new product nation-wide distribution.

Method of Conducting Research Studies.—Research calls for the gathering of facts in an impartial manner. The scientific method is the same whether applied to physics, biology, chemistry or marketing. It begins with the gathering of facts, continues with the registration and measurement of the data obtained, is followed by tabulation and charting of the information, and finally the drawing of conclusions. There are many different ways employed to obtain the facts. The examination and the extraction of the data from existing books and records, personal interviews, mail questionnaires and the actual recording of the necessary data while the process of

marketing being studied is in progress, are some of the methods which are employed to obtain the facts needed. Sometimes these data may be supplemented by statistical information which has already been gathered and tabulated by others.

Marketing Research and the Individual Farmer.—How will the individual farmer benefit by marketing research? An apple producer, for example, may have several alternatives from which to select his method of sale. The country dealer or shipper, the commission merchant in the city, the trucker-dealer who buys outright at the farm, the nearest public market, the roadside market, the local store, the local co-operative association and the exporter, might constitute the outlets for the apples which this particular farmer produces. Marketing research would help this producer to select the method of sale which has returned to producers in his community the higher average price for apples over a period of years. The location of the farm with respect to consuming centres, public markets and good highways, would, of course, influence the price obtained from these various agencies. Marketing studies to determine the grade, the variety or varieties, the size and type of containers which command the highest prices from the jobber, the retailer and the consumer, would be of vital interest to an individual farmer.

In addition to our domestic market for apples, we have an export market. Studies of the varieties, the size, the colour, the grade and the size and type of container, which best meet the requirements of the fruit trade and the consumers in the United Kingdom, would be very useful to individual Canadian fruit growers. Studies of approved methods of ocean shipments and of the manner of selling competing fruits, would, if properly made, yield good returns for the time and money spent on such investigations.

It was found that the most important factor lowering the price of Maine potatoes in large city markets were broken and injured tubers. Injuries of this kind can be controlled by careful production and harvesting methods but it was necessary to carry on marketing studies to show the importance of this price limiting factor.

Marketing studies have shown that some farmers regularly obtain better prices than others Careful analysis of the product, the package, the variety, the method of shipment, the method of harvest, the kind of seed sown, the cultural methods used and the type of soil in which the product was grown by the farmer who receives the higher prices, would be of great help to those farmers who always receive the lower prices for the same commodity. One of the outstanding functions of marketing studies is to learn what, where, how and when to produce various kinds of farm commodities if the highest possible returns are to be obtained from their sale.

There are definite principles underlying the marketing of farm commodities as there are underlying their production but these marketing principles can only be determined after the facts have been obtained and analysed.

C. M. Collins, Agricultural Representative for Annapolis County, Nova Scotia, is the author of a bulletin entitled "A Study in Apple Returns" which has been published by the Nova Scotia Department of Agriculture. One of the important results reported was that "The four-year weighted average warehouse price for ten varieties of apples of all grades and sizes varied in warehouse records examined by as much as 41 cents per barrel. In other words one warehouse packing out 33,746 barrels of these ten varieties over the four years, distributed $13,835 more to its members during that period, than it would, had its price been on a level with the lowest warehouse."

C. S. Orwin, Agricultural Economics Research Institute, Oxford University, writing in the April issue of "The Scottish Journal of Agriculture" states "It is at once apparent that the item of labour in the total cost of the product would be very much higher in British agriculture, if farming in this country were conducted under a system of labour organization similar to that in competing countries, and it follows that only by the adoption of other methods of management designed to raise the efficiency of the labour employed can the British farmer expect to maintain his position in an open market."

FINANCIAL STATEMENTS[1]

W. F. Chown[2]

The purpose of accounting is to build up a record of business transactions from which statements can be prepared at any time to show the actual financial position of the business and the profit or loss to the owner. Accounting is an art, not an exact science, and some knowledge of the principles involved and terminology employed should be of value in preparing simple financial statements and in the interpretation of the more difficult ones.

Description of Statements in Common Use.—The Statement of Assets and Liabilities is prepared at the beginning of any business enterprise or at the installation of its first systematic accounts, and thereafter at the end of each financial period or at any time special circumstances may demand. It is designed to show the financial position of a business at a given time. When drawn up in account form, the Assets are ranged upon the left-hand side and the Liabilities upon the right. The Excess of Assets over Liabilities represents the net worth of the business. During the period of operations, changes occur from day to day in the value of Assets, Liabilities and Net Worth. The profit or loss for any period may be determined by comparing such statements prepared at the beginning and end of the period. Subject to adjustment for additions or withdrawals of capital, an increase in the value of Net Worth represents a profit, and a decrease, a loss Such a comparison determines the amount of profit or loss, but does not explain it

The Statement of Income and Expenditure is prepared at the end of any financial period to explain as fully as may be needed the manner in which the profits have been earned or the losses incurred. When drawn up in account form, the various classes of income are ranged on the right-hand side and the various classes of expenditure on the left. An Excess of Income over Expenditure is a profit, and an Excess of Expenditure over Income is a loss

The Balance Sheet is a statement of assets and liabilities prepared from books kept by double entry, whereas a Statement of Assets and Liabilities may be prepared from single entry records, estimates, appraisals or any method except that employed in double entry bookkeeping The Profit and Loss Account is a statement of income and expenditure prepared, like the Balance Sheet, from books kept by double entry.

The Statement of Assets and Liabilities.—This Statement is a necessary basis for the installation of accounting records and also it is the necessary basis for all loans. To the prospective lender, it serves two main purposes: (1) basis of analysis for short term credit, and (2) basis of analysis for long term credit, and will be reviewed differently according to the term of the prospective loan

Classification of Assets and Liabilities.—The proper classification, grouping and valuation of Assets and Liabilities are the prime requisites.

Current Assets include cash and those assets which will be converted into cash in the ordinary course of the business, e.g. notes and accounts receivable, produce or live stock intended for sale by a farmer, or butter on hand in a creamery. Fixed Assets are those of a permanent nature purchased or acquired for the purpose of earning income and not for sale, e.g. land, buildings, machinery, the herd of a dairy farmer. Other Assets may include deferred items, such as supplies or seed on hand, not for sale; prepaid items, such as insurance or rent, the value of which has not yet been consumed; and investments that will continue to be held while the business remains a "going concern."

Current Liabilities are the debts due at the date of the Statement or that will be presently payable, e.g. bank loans, accounts payable, machinery and other notes coming due during the current year, accrued wages or taxes—in short, those items that will be payable out of current funds. Fixed Liabilities are long term debts, the payment of which is deferred to a definite future time, e.g. mortgages. The Excess of

[1] To be continued.

[2] Accountant Examiner, Economics Branch, Department of Agriculture, Ottawa.

Assets over Liabilities shows the net worth of the business to its owner or owners. It consists of the original capital, plus additions of capital or earnings, less withdrawals of capital or operating losses incurred.

Valuation of Assets.—To the banker reviewing a statement for the purpose of determining whether an extension of credit is advisable or not, the current assets and liabilities will be of chief interest. These are the resources from which he may expect to receive repayment, set off against those obligations that must be paid in priority to this loan. This group of assets, then, should be valued at their realizable value. The usual rule in valuing merchandise inventory is "at cost or market, whichever is lower" In farm work, because the cost is not usually known, it is reasonable to value produce and live stock held for sale at a fair market value on the farm.

There are several bases on which fixed assets may be valued, but the conventional way is at cost, less depreciation to date. Land, properly worked, does not depreciate; buildings and fences depreciate at from 2-4% per year; machinery at approximately 10% per year. Horses, dairy cattle and beef breeding stock should be valued individually. Their value will increase to maturity and then will have to be reduced because of depreciation Be conservative in this and all other valuations. The valuation of fixed assets and particularly land, buildings and machinery does not necessarily coincide with and may differ widely from present realizable value or from present replacement value; this section is somewhat historical in character, showing the cost of the assets less the value estimated to have been consumed to date and actually charged to operations.

Other Assets may properly be valued at cost, or, if that is not known, present market value or at the remaining unconsumed value in the case of prepaid insurance.

Illustration.—Statements I and II below illustrate the greater clarity that is achieved by a proper grouping.

I

THOMAS BROWN

STATEMENT OF ASSETS AND LIABILITIES

March 31, 1935

ASSETS		LIABILITIES	
Land and buildings	$ 9,600 00	Machinery note	$ 80.00
Feed and seed	410 00	Mortgage and interest	4,240.00
Machinery and equipment	900 00	Accounts payable	100 00
Live stock	1,785 00	Excess Assets over Liabilities	8,636 50
Cash and bank	114 50		
Insurance prepaid	65 00		
Milk cheque	182 00		
	$13,056 50		$13,056 50

Results Obtained by Re-arrangement.—From Statement II, it is readily apparent that obligations amounting to $420.00 are presently payable, and that there are on hand cash and other resources that will soon be converted into cash, amounting to $581.50, leaving $161.50 free for running expenses. Prepaid expense items to the value of $375.00 are also shown. With these facts, and some additional information with respect to prospective earnings and expenses, it should be possible to determine the expediency of a loan

The original cost of the Fixed Assets and the provision for depreciation to date are plainly shown so that the reader is in a position to judge of the adequacy of this provision. The mortgage of $4,000.00 is set opposite the real estate by which it is secured. It is evident that Net Worth is represented to the extent of $8,100.00 by an investment in Fixed Assets.

In statement I above, these facts are obscure whereas in statement II, they are either obvious or can be easily deduced. The same valuations have been used in both statements so that the improvement as a means of giving information has been achieved by a rearrangement of the same essential data.

II
THOMAS BROWN
Statement of Assets and Liabilities
March 31, 1935

Assets

Curren Assets.—			
Cash on hand and in bank		$ 114 50	
Milk cheque receivable		182 00	
Live stock for sale		185 00	
Seed grain for sale		100 00	
Total Current Assets			$ 581 50
Fixed Assets —			
Land		$ 6,000 00	
Buildings	$ 6,000 00		
deduct, provision for depreciation	2,400 00	3,600 00	
Farm machinery and equipment	$ 1,800 00		
deduct, provision for depreciation	900 00	900 00	
Dairy cattle		1,000 00	
Horses		600 00	
Total Fixed Assets			12 100 00
Other Assets.—			
Feed and seed on hand		$ 310 00	
Insurance prepaid		65 00	
Total Other Assets			375 00
Total Assets			$13 056 50

Liabilities

Current Liabilities —		
Accounts payable	$ 100 00	
Mortgage interest	240 00	
Machinery note	80 00	
Total Current Liabilities		$ 420 00
Fixed Liabilities —		
Mortgage at 6% due 1939		4,000 00
Total Liabilities		$ 4 420 00
Net Worth —		
Excess Assets over Liabilities		8,636 50
Total Liabilities and Net Worth		$ 13 056 50

AMENDMENTS TO THE CANADIAN FARM LOAN ACT, 1935

The Canadian Farm Loan Act of 1927 amended by the Parliament of Canada in 1934,[1] was radically modified by the Canadian Farm Loan Act Amendment Act, 1935.

Canadian Farm Loan Board.—Under the original act, the Board set-up in 1929 consisted of four members: the Minister of Finance was ex officio chairman of the Board and the Commissioner the chief executive officer. By the terms of the amending legislation, 1935, the Board shall consist of not less than three, nor more than five members, and the Commissioner will be Chairman The Deputy Minister of Finance or the Comptroller of the Department of Finance shall be one of the members of the Board.

The Advisory Council to the Board consisting of the Provincial Treasurer of each Province of Canada in which a provincial Board was organised, and the chief executive officer of each provincial board has been abolished, and the Board may appoint for any province or for any two or more provinces in which it operates, a chief executive officer to have charge of the operations of the Board in such province or provinces. This officer will, upon appointment, exercise all the powers and duties conferred upon him by the Board. A local loan advisory board of not more than three members may be appointed by the Board and the chief executive officer is ex officio-member and chairman of it.

Capital Requirements.—Under the Act of 1927, the Government of Canada was authorized to subscribe initial capital to an amount not exceeding $5,000,000 for purposes of the Board. For a period of three years this initial capital was free from interest after which it drew 5% per annum and was repayable out of earnings of the Board after providing a reserve fund at least equal to the total repayments including the repayment then proposed to be made. In addition to this source of capital, the Board was authorized to issue capital stock of one dollar each. The Federal Government and the Government of each province in which loans were made were both required to subscribe for capital stock to an amount equal to 5% of the total amount of principal outstanding on loans made in such province by the Board. Each borrower was also required to subscribe to the capital stock to an amount equal to 5% of the sum borrowed by him

This section of the Act has been amended in order to permit the Government to fix the rate of interest on initial capital advances and to eliminate the requirements for the purchase of capital stock in the Board by provincial governments and borrowers. The Government of Canada will provide the Board with initial capital to an amount not exceeding $5,000,000 on the same conditions as previously set up, that is free from interest charges for a period of three years after which time interest shall be paid at such rate as the Governor in Council shall direct instead of five per cent per annum as stated in the Act of 1927. The Board shall annually carry to reserve fund 25% of the net earnings of the Board until it equals 25% of the paid capital stock of the Board and thereafter at least 10% of the net earnings.

The Minister of Finance may purchase at a price not exceeding the par value, the capital stock already subscribed for by the provinces. The Board may also retire the outstanding capital stock subscribed by a borrower under the Act, by crediting the amount of the par value of such stock as a payment upon his loan and the borrower ceases to be a stockholder of the Board.

The outstanding Farm Loan bonds shall not exceed at any time twenty times the paid-up capital stock subscribed for by the *Government of Canada* instead of the *borrowers* as provided in the Act of 1927.

Purchase of Bonds by Minister.—The Minister of Finance may purchase from time to time on behalf of the Dominion of Canada, bonds issued by the Board to an amount not exceeding fifty million dollars at any one time, and the Governor

[1] See Economic Annalist, Vol. IV, No. 3, pp. 43-45.

in Council may further authorize the guarantee of the principal and interest of Farm Loan bonds to the amount of forty million dollars. Since an amount of $10,000,000 has already been loaned to farmers, the Board will have $80,000,000 available for new loans.

Loans.—Before an applicant can have his application considered by the Board, it is necessary that he come within the definition of farmer, which, under the Act means: A person whose principal occupation consists of farming which includes stock raising, dairying and the tillage of the soil.

Loans may be made only to farmers actually engaged or shortly to become engaged in the cultivation of the farm mortgaged and whose experience, ability and character are such as to warrant the belief that the farm to be mortgaged will be successfully cultivated, provided that no loan shall be made on the security of unimproved land except for the purpose of making improvements on it.

Loans on First Mortgages.—Under the Act of 1927 no loans were granted in excess of 50% of the Board's appraised value of the land and 20% of the value of buildings to a maximum loan of $10,000. The maximum amount of a loan was reduced to $7,500 by the amending legislation of 1934 and to $5,000 by that of 1935. The basis of valuation, however, has been changed in 1935 and loans shall be made only where the Board can hold first mortgages on farm land up to 50% of the Board's appraised value of land and buildings. The interest rate on such loans has been fixed at 5% per annum.

The proceeds of the loan may be used for the following purposes: to purchase farm land, fertilizers, seed, live stock, tools, machinery and any implements and equipment necessary to the proper operation of the farm mortgaged; to erect farm buildings or to clear, drain, fence or make any other permanent improvement tending to increase the productive value of the land; to discharge liabilities already accumulated; or for any other purposes which in the judgment of the Board may be reasonably considered as improving the value of the land for agricultural purposes.

Loans on Second Mortgages.—In any case where the Board granted a loan on the security of a first mortgage and where such a loan will not be sufficient to discharge the indebtedness of the farmer to provide for all his reasonable and necessary requirements a further loan of $1,000 may be secured on the security of a second mortgage for a period of not more than six years on farm lands in the provinces where chattel security may be taken by the Board on live stock and other personal property. In such provinces, however, the aggregate loan shall not exceed two-thirds of the appraised value of land and buildings given as security and, in any province where chattel security may not be taken, only 60% of the value of land and buildings. A loan granted on second mortgage cannot exceed one-half the amount advanced on the security of the first mortgage and in any case, the maximum aggregate loan which may be made to a farmer is $6,000. The interest rate on loans made on a second mortgage shall not exceed the current rate charged in respect of first mortgage loans by more than 1% per annum.

Repayment of Loans.—By the terms of the amending legislation, every loan is repayable upon such terms and within such periods not in excess of twenty-five years as the Board may prescribe. However, all loans repayable over a period in excess of five years shall be paid in equal annual or semi-annual instalments of principal and interest. The rate of interest to be paid by borrowers on defaulted payments and arrears in taxes and other charges assumed by the Board has been fixed at 5½% for the time being and shall not exceed 8% per annum.

Relationship to Farmers' Creditors Arrangement Act, 1934.—The purpose of these amendments to the Farm Loan Act is to provide farm mortgage credit at reasonable rate to farmers particularly when the result will be the consolidation of their indebtedness under the provisions of the Farmers' Creditors Arrangement Act or otherwise.

Whenever a proposal for a composition, extension or scheme of arrangement made under the Arrangement Act has been duly approved, the holder of a mortgage may secure from the Farm Loan Board a loan not exceeding one-quarter of the principal amount of the mortgage assigned or hypothecated, for a period of one year with possible extension of time for repayment of such loan upon approval of the Board. The proceeds of this loan, however, have to be passed to the farmer for the proper operation of the farm covered by the first mortgage. The rate of interest on such loans shall not be in excess of that payable on the mortgage assigned or hypothecated and in no case more than 1% in excess of the rate charged the mortgagee by the Board.

Provincial Legislation.—The amending legislation completely eliminates the principle of dual control as between the provinces and the Dominion. Administration will now be entirely and directly in the control of the Canadian Farm Loan Board, which will be able to make loans in all provinces instead of, as previously, only in those provinces which passed the necessary legislation required by the Dominion statute.

In 1931 the Quebec Legislature enacted legislation empowering the Provincial Government to contribute to the interest payable by borrowers in the province of Quebec up to 1½%, thus reducing to 5% the rate of interest on loans granted by the Canadian Farm Loan Board. In 1935 the Quebec Legislature amended this legislation in order that the rate of interest payable on farm loans by Quebec borrowers be not more than 3%.

The Eleventh American Institute of Co-operation will be held at Cornell University, July 15–20. The Institute will emphasize instruction in co-operation: "It will be more of an instructional character with closely co-ordinated lectures thoroughly explaining various aspects of the business problems of agricultural co-operatives. These lecture courses will be supplemented by intensive conferences developing more detailed aspects of the various problems coming before the Institute" said C. W. Holman, Secretary of the Institute in a preliminary announcement.

Nearly 100 farmers are completing cost account records in co-operation with the Department of Agricultural Economics and Farm Management, Cornell University. In the past twenty years, operators of farms, on which cost accounts have been kept, have obtained labour incomes averaging $634. For the seven-year period 1914 to 1920, a period of high prices, incomes averaged $1,241. From 1931 to 1933, when prices were very low, labour incomes averaged minus $811, whereas during the period 1921–30, the average was $644. This was a period of fairly stable prices.

ECONOMIC LITERATURE

ALLEN, WILLIAM, HOPE, E. C., and HITCHCOCK, F. C. Bulletin 64. Studies of Probable Net Farm Revenues for the Principal Soil Types of Saskatchewan Department of Farm Management, College of Agriculture, University of Saskatchewan, Saskatoon.

The writers of this bulletin have utilized the results of farm management surveys conducted during the past ten years in various sections of Saskatchewan to predict probable operating costs and revenues for twenty-four farms of different sizes representing the several soil types of that Province. The purpose of this report is to present conservative estimates of the costs likely to be incurred in farming in areas typical of the province and of the revenues that may be expected from farms of representative sizes in these areas during the next decade. Estimates of probable costs that may be anticipated are based upon farm survey experience with considered adjustments. Crop yields and grades are based on an average prevailing in the various areas between 1918 and 1930. The organization of the farm has been assumed to continue with little change. It is also assumed that farms of one section or less in size will be operated with horse draft power. Prices for both crops and live stock have been estimated

on the basis of the five-year average between 1910 and 1914 and adjustments for varied conditions in the different areas have been made. Farm expenses follow closely those obtaining in the regional surveys which have been completed, with modification to allow for changes in the price level. On farms of less than a section of land, no allowances have been made for operating an automobile but the expense of a driving horse has been allowed. An automobile of low value has been included as part of the standard equipment on the farms of a section or more. Living costs were considered for only a moderate standard of living and would not provide for extensive replacements of furnishings and clothing.

Financial Summary.—The net cash income represents the probable return to the farm operator and his family for their labour contribution (called the net income) and the non-cash items of expense that may be expected in building and equipment maintenance. On the basis of the net incomes shown for the representative farms, the maximum obligations that can be undertaken have been determined by reference to amortization tables and are presented for periods of fifteen and twenty years with interest at six and seven per cent for each of these periods.

A detailed operating statement is set forth for each type of farm which is summarized in the bulletin as presented below —

SUMMARY OF STATEMENTS OF NET CASH INCOMES, NET INCOMES AND DEBT CARRYING CAPACITY OF FARMS INCLUDED IN BUSINESS STUDIES

Soil type	Average yield of wheat 1918-1930	Size of farm			Net cash income	Net income	Debt that can be amortized by net income at 6% in 20 years
		Total acres	Acres of crop-land	Acres of crops	$	$	$
Inferior prairie	9 8	320	153	153	−137	−236	Nil
	9 8	640	303	293	458	267	3,062
Average prairie (B)	11 3	320	301	211	312	49	562
	11 3	640	598	406	856	597	6,848
Poor prairie	12 5	320	203	130	−242	−332	Nil
	12 5	640	397	257	− 25	−307	Nil
Fair prairie	13 1	320	242	167	137	4	Nil
	13 1	640	450	365	1053	859	9,852
	13 1	1280	902	732	3212	2374	27,230
Average prairie (A)	13 6	320	250	181	228	42	482
	13 6	640	485	356	985	703	8,086
Fair to good southern park	15 4	320	229	166	269	114	1,308
	15 4	640	465	330	1085	796	9,130
Very good park and prairie	16 4	320	268	181	510	307	3,521
	16 4	640	546	363	1611	1280	14,704
Fair to good eastern park	16 7	320	194	139	134	− 10	Nil
	16 7	640	360	262	760	523	6,000
Average northern park	19 0	320	183	148	419	262	3,005
	19 0	640	303	230	805	547	6,286
Best park	19 0	320	221	161	692	432	4,955
	19 0	640	448	393	1978	1491	17,102
Best prairie	20 0	320	295	189	778	516	5,917
	20 0	640	596	380	2127	1588	18,214
	20 0	1280	1180	780	7025	5788	66,388

The authors point out that in this publication "many shortcomings will be apparent.

NOTES

Thirty-eight (38) marketing schemes have been submitted to the Dominion Marketing Board for consideration. Of these, eleven (11) have been approved, and are in operation. Three were voted on and the percentage of voters favouring them was not considered sufficient by the Minister to approve them. One was not acted upon as the proposal was not considered expedient. Six (6) were returned to the petitioners; in four cases the principal market for the product to be regulated was within the province of production and, therefore, could not be considered as coming within the scope of the Act and in the other two cases, the products were not natural products as defined by the Natural Products Marketing Act. Seventeen (17) schemes are now under consideration by the Dominion Marketing Board.

A. Fulton, Representative of the Ontario Fruit Growers' Association in Great Britain, reports that there has been a marked reduction in the number of slack barrels of apples shipped to that market during the present season. This is attributed to prompt shipment of apples from ordinary storage early in the season. During the late season, there was a higher percentage of "slacks" which is largely attributed to loose packing and failure "to plug" the barrels. A few shipments were forwarded without pads. The condition of the apples was reported to be very satisfactory.

The general index number of prices of agricultural produce in Great Britain monthly average (1911–13 = 100) was 112 in March. This was three points below the index for February but 4 points above that for March, 1934, and 10 points higher than in March, 1933. If payments under the Wheat Act and the Cattle Emergency Act had been taken into consideration, the index would have been 119. Lower prices for liquid milk and fat cattle contributed largely to the lower index for March, 1935.

H. R. Hare, Economics Branch, Department of Agriculture, Ottawa, is acting as Secretary of a subcommittee appointed by the National Barley Committee to study feed problems. W. R. White, of the Seed Branch who is Chairman of the Subcommittee, and Mr. Hare recently visited sections of Western Ontario in order to obtain information from feed dealers, elevator companies and farmers.

The Secretary of the International Conference of Agricultural Economists has advised that preliminary plans are being made for the fourth conference to be held in Scotland during the late summer of 1936. Proceedings of the third conference held at Bad Eislen, Germany, will soon be available. Dr. J. F. Booth, Economics Branch, Department of Agriculture, is the Canadian correspondent to the International Conference.

The Canadian Society of Agricultural Economics will hold its seventh annual meeting at the University of Alberta, Edmonton, in conjunction with the annual meeting of the Canadian Society of Technical Agriculturists. Sessions will be held each morning June 25th to 27th inclusive. Agricultural Policy, Farm Indebtedness, Land Appraisal, Credit, and Recent Changes in Marketing will be general topics for discussion.

The 1935 acreage of wheat in Europe is reported to be slightly larger than last year. Winter damage has been confined to comparatively small areas but drought has affected the crop in Spain and Italy. Conditions have also been unfavourable in North Africa and production will likely be appreciably less in this area.

A study of potato production in the Saint John Valley, New Brunswick, will be carried by the Economics Branch of the Dominion Department of Agriculture and the Department of Agriculture for New Brunswick. Field work will be commenced about the first of July.

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INVESTIGATIONS ON BLACK KNOT OF PLUMS AND CHERRIES

IV. STUDIES IN PATHOGENICITY AND PATHOLOGICAL HISTOLOGY[1]

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In this article, concluding the present investigations on black knot, studies on pathogenicity and pathological histology of the host are the two major phases under consideration, while varietal susceptibility and certain experiments in control are dealt with in a minor way.

REVIEW OF LITERATURE

Farlow (*1*) in 1876 stated that "we have made direct experiments to show that the spores of the knot on the choke cherry will germinate and produce the knot in healthy plum trees." He did not cite the method by which these results were obtained In 1913 Gilbert (*3*) reported some cross-inoculation experiments. He used the following methods: "(1) Spores sprayed from time to time on actively growing branches. (2) By means of finely-pointed glass tubing spores injected into stems at various depths from cambium region outward. (3) Incisions were made in the bark into which was placed a drop of culture medium containing germinating spores. (4) Small side branches were partly torn from the main stem and a spore suspension introduced into the wound. They were then covered with grafting wax or paraffin. Cross-inoculations were made between choke cherry, wild plum, cultivated plum and cherry using ascospores and conidia." He states that in no single instance was there the formation of any typical knot. As a check on these experiments inoculations were made upon the choke cherry using spores from other choke cherries, and normal knots were obtained. Gilbert did not cite which of the methods proved successful nor did he give his method of obtaining either pure cultures or suspensions of ascospores and conidia.

Humphrey (*5*) in 1893 reported numerous unsuccessful attempts to inoculate plums with pycnospores which he claimed to have obtained by culture from ascospores.

Stewart (*13*) in 1914 made a worthy contribution on the pathological anatomy of black knots. He sectioned knots in almost all stages of development and enumerated in careful detai the anatomical features of diseased and healthy tissues of *Prunus virginiana* L.

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PATHOGENICITY STUDIES

In order to ascertain the infection capabilities of ascospores and conidia of *D. morbosum*, and, if possible, some of the conditions governing infection, experiments involving more than 900 inoculations were conducted over a period of five years.

During the first year the majority of inoculations were made as follows. The surface of the branch was first sterilized with mercuric chloride (1 : 1000) and washed with sterile water after which the branch was injured to the cambium with a scalpel and the inoculum was inserted. The inoculated wound was then covered first with moist blotting paper and then with wax paper. All inoculations during this year (1930) were made on branches more than one year old and the inoculum used was in many cases a *Coniothyrium* sp., which was later proved not to be a pycnidial stage of *D. morbosum* (*8*).

In 1931 the method of inoculation was in some cases similar to that used during the previous year. In others the surface of uninjured current season twigs in protected positions on the trees were either atomized, or painted by means of a camel's hair brush, with aqueous suspensions of conidia from pure cultures of *D. morbosum*. In order to improve chances of infection when dry weather followed inoculation, twigs were in some cases atomized with spores a second and sometimes a third time.

In 1932 methods of inoculation were similar to those of the previous year with the exception that pure suspensions of ascospores of *D. morbosum* obtained by allowing mature perithecia of *D. morbosum* to eject their ascospores into water, were used as inoculum.

During the following two years two other methods were also employed. One of these was a modification of the method used by Keitt (*6*) in his peach scab investigations, by which wicks from Erlenmeyer flasks containing water were wound loosely around inoculated current season twigs. On other occasions "patch grafting"[3] was resorted to, by means of which small sections of unswollen host material taken from just beyond the borders of visible knot swellings where mycelium of *D. morbosum* was assumed to be present were grafted onto healthy branches. During May 1934 seventy-six grafts were made, some of which were from *P. domestica* onto the same host while others were made from *P. domestica* onto *P. cerasus* and sweet cherry. Branches of all ages were used in making these grafts.

The details of these experiments are summarized in Table 1.

An examination of Table 1 reveals the following facts. During 1930 only one knot developed as a result of inoculation by the first method. During 1931, when current season twigs were inoculated with conidia (1) during May, six typical knots were produced, and (2) during June, three knots developed. On all of these, conidia of *Hormodendrum* were produced and on eight of them perithecia of *D. morbosum* finally developed. All of the above-mentioned knots originated on current-season twigs and all were visible during the fall of the season of infection, conidia of *Hormodendrum* being produced on one during the fall and on the remaining eight the following spring. Mature perithecia of *D. morbosum* developed on one knot within a year after infection and within two years on seven others.

[3] R. V. Harris of East Malling Research Station kindly loaned his instruments (developed by Roach (*11*)) for these experiments.

TABLE 1.—SUMMARY OF BLACK KNOT INFECTION EXPERIMENTS IN WHICH POSITIVE RESULTS WERE OBTAINED

Inoculations			Inoculum used		Results
Date	Material and method	Host	Source	Type	
13 6 30	Large branch injured inoculum inserted, covered 14 days	Reine Claude plum	Fruiting surface of knot on Lombard plum	Conidia of *Hormodendrum* sp plus knot tissue	20 9 30 Tissues swollen in vicinity of area of inoculation 31 8 31 Small area of swollen portion bearing conidia of *Hormodendrum sp.* (1/15)* 1 8 32 Knot two inches in length bearing conidia.
9 4 31	Branches ½"–¾" in diameter, injured, inoculum inserted, covered 14 days.	Lombard plum	Monoascospore culture from knot, Lombard plum	Conidia of *Hormodendrum* sp plus knot tissue	1 6 31 Three branches swollen with rough surface 1 9 32 Knot-like in appearance but no appearance of conidia
22 5 31	Current season twigs, uncovered inoculum painted on	Lombard plum	Monoascospore culture from knot, Lombard plum	Conidia of *Hormodendrum* sp plus knot tissue	2 9 31 Small swelling on two twigs. 1 11 31 Small swelling on three twigs (3/10) 4 6 32 Knots producing conidia of *Hormodendrum* sp on all three twigs 14 5 33 Mature perithecia of *D morbosum* on two of the three knots
1.5 31	Branches ½"–1" in diameter injured, inoculum inserted, covered 12 days.	*P. cerasus*	Monoconidial cultures from knot, Lombard plum	Conidia *Hormodendrum* sp. plus *Coniothyrium* sp	28 6 31 Swollen areas with rough surfaces on four inoculated branches 14 8 32 All branches swollen but no appearance of conidia.
21 5 31	Current season twigs, inoculum painted on	Lombard plum.	Monoascospore cultures from knot, Lombard plum	Conidia of *Hormodendrum* sp	20 8 31 Small swelling on one twig 19 9 31 Small swelling on three twigs (3/10). 9 6 32 Three knots producing conidia of *Hormodendrum* sp 22 4 33 Three knots producing perithecia of *D. morbosum*

TABLE 1.—SUMMARY OF BLACK KNOT INFECTION EXPERIMENTS IN WHICH POSITIVE RESULTS WERE OBTAINED—*Concluded*

Inoculations			Inoculum used		Results
Date	Material and method	Host	Source	Type	
12.6 31 14 6.31 18 6.31	Current season twigs, inoculum painted on.	Lombard plum	Monoascospore cultures from knots Lombard plum.	Conidia	1 9 31 Three knots developed on two twigs. Conidia of *Hormodendrum* sp. on one knot. (2/64).† 19 4 32 Mature perithecia of *D. morbosum* on small fruiting area of one knot. 15 6 32 Conidia on other two knots. 1 5 33 Mature perithecia of *D. morbosum* on three knots.
7 5 32	Branches one year old bearing current season twigs, inoculum painted on.	Lombard plum	Knot, Lombard plum	Ascospores	18 9 32 Knots appearing on two current-season twigs Conidia of *Hormodendrum* sp. on both knots (2/10) 1 4 33 Mature perithecia of *D. morbosum* on two knots.
2 5.32 10 5 32 15 5 32	Branches one year old bearing current season twigs, inoculum painted on.	Lombard plum	Knot, Lombard plum	Ascospores	1 9 32 One knot appearing on current-season twig (1/5) 14 6 33 Conidia of *Hormodendrum* sp. on knot. 15 5 34 No perithecia of *D. morbosum* developed on this knot.
7 5.32 10.5 32	Branches one year old bearing current season twigs, inoculum painted on.	Lombard plum	Knot, Lombard plum	Ascospores	1 9 32 Two knots on current-season twigs, both producing conidia of *Hormodendrum* sp (2/6) 1 4 33 Perithecia of *D. morbosum* on one knot.
9 5 32	Branches one year old bearing current season twigs; inoculum painted on.	Reine Claude plum.	Monoascospore cultures from Lombard plum.	Conidia.	1 9 32 One knot on current season twig producing conidia (Plate I, figures 1–3). (1/5). 30 4 33 Perithecia of *D. morbosum* on knot.

7.5 33	Current season twigs (Keitt's method, see text).	Reine Claude plum.	Monoascospore culture from Reine Claude plum	Conidia.	25 9 33 14 5 34	Three knots on two twigs. All producing *Hormodendrum* conidia (2/6) Perithecia of *D morbosum* on two knots.
10 5 33	Current season twigs (Keitt's method, see text).	Lombard plum.	Monoascospore culture from Reine Claude plum	Conidia of *Hormodendrum* sp	25 8 33 4 9 33 14 5 34	One knot on twig (1/4). Knot producing conidia of *Hormodendrum* sp. No perithecia of *D. morbosum* on this knot
10.5 33	Current season twigs (Keitt's method, see text)	Lombard plum.	Monoconidial culture from Lombard plum	Conidia of *Hormodendrum* sp	20 9 33 1 9 34	Five tiny knots on one twig (1/5). No further development. (Small mechanical injury at base of twig.)
4 5 34	"Patch-grafting"	Lombard plum	Unswollen bark from Reine Claude containing mycelium of *D morbosum*.		15 8 34	Knots on three grafted branches, all of which produced conidia of *Hormodendrum* sp. (3/76) ‡

*The numerator refers to the number of branches which developed typical black knot infection while the denominator refers to the number of branches or twigs inoculated in the series.

†Denominator refers to total number of inoculations made during June 1931, 1932 and 1933.

‡Denominator in this case refers to total number of patch-grafts made.

It will also be observed that when infection courts were provided on branches more than one year old on various hosts swellings developed in some cases though typical knots were never produced (Figure 1, A and B), (Plate I, 4). Some of these swe lings had all the appearance of normal knots during their first year except that conidia were apparently not produced.

During 1932 when ascospores and conidia were used as inoculum on current season twigs as in the previous year six typical knots developed, of which five were produced as a result of inoculations with ascospores of *D. morbosum* and one as a result of inoculating with *Hormodendrum* conidia. Conidia of *Hormodendrum* sp. developed on all six knots and perithecia of *D. morbosum* developed on four. On five of these knots *Hormodendrum* conidia appeared during the fall of the year of infection and on four, perithecia of *D. morbosum* developed in less than one year after the inoculations were made.

During 1933 by the use of Keitt's method nine knots developed as a result of inoculating with *Hormodendrum* conidia. Five of these appeared on a single twig (Plate I, 5) during the fall of the year of infection but developed no further. The failure of these five knots to continue their development was directly ascribed to a mechanical injury which the base of the twig received during the following winter. The twig itself, though somewhat delayed in development the next spring, was not killed and the presence of the fungus in the swellings one year later was determined by sectioning. It has frequently been observed during the present investigations that a delicate balance exists between *D. morbosum* and the host, and that any serious disturbance of the growth of the host reflects unfavourably on the pathogen, frequently resulting in its death.

Perithecia of *D. morbosum* developed on 2 knots produced in 1933, within a year after inoculation.

In 1934 three knots developed on branches of Lombard plum as a result of "patch grafting". One of these is illustrated in Plate I, 6. Branches on which grafts were successful were two years old in two instances and considerably older in the other case.

It will be observed that perithecia of *D. morbosum* did not always develop on artificially produced knots which developed conidia. This was accounted for in most instances by parasitism of the stroma by *Cephalothecium roseum* though in a few cases it is possible that some other factor or factors may have prevented their formation.

From the numerical standpoint it will be observed that only a small percentage of the inoculated branches or twigs developed black knots. Out of a total of 622 branches or twigs inoculated with ascospores or conidia of *D. morbosum* 19 (3%) developed black knot infection. However, 16 (84%) of these twigs were inoculated during May and the remaining 3 were inoculated during early June. If percentage infection is calculated on the basis of number of twigs infected, 26% of the twigs inoculated during May developed one or more knots. On the other hand, if calculations are made on the basis of number of knots in proportion to number of inoculated twigs, 34% infection was obtained during May.

The outstanding features of the foregoing infection experiments may be summarized as follows: (1) Typical black knots were produced on

P. domestica inoculated with either ascospores of *D. morbosum*, conidia of the imperfect stage (*Hormodendrum* sp.) or host tissue containing mycelium of *D. morbosum;* (2) though branches of all ages were inoculated with spore suspensions of *D. morbosum* typical black knots developed only on current season twigs in all cases except one; and (3) though inoculations were carried out at all times of the year only those made during May and early June were successful.

It is realized that only partial success was obtained with any method of inoculation used in the foregoing infection experiments. The latter are open to the criticism that they were conducted outdoors where the inoculated twigs were unprotected from chance infection by the black knot pathogen from the unsprayed check trees. Since, however, all experiments, including controls were conducted on sprayed trees, in the majority of cases in a young orchard some distance from the unsprayed trees, and since in nearly all cases the only knots present on the trees were the knots which developed on inoculated twigs (several knots on a twig in some cases), it would seem highly improbable that any of them developed as the result of chance infection.

A Brief Consideration of Factors Involved in Black Knot Infection

A consideration of the factors governing infection of *Prunus* spp. by the black knot pathogen must include temperature, relative humidity, amount and type of inoculum, and stage of host development.

Temperature

The average temperatures for the first week subsequent to the inoculations summarized in Table 1 varied from 10 5° C. to 15° C. These temperatures are relatively low and while it has been shown that *D. morbosum* grows quite rapidly on culture media at temperatures even lower than those cited above, it was found that the organism also grew rapidly at much higher temperatures. Therefore, it cannot be expected that temperature is the factor limiting the period of infection to approximately one month of the year.

Relative Humidity

In those cases where infection occurred the relative humidity for the first week after inoculation was always high, the average varying from 76 to 90%. It can be assumed from this that relative humidity must be high for some days after inoculation, before infection is possible. But an examination of the meteorological records showed that at many other times of the year the relative humidity was high and the temperature apparently favourable for a considerable length of time after inoculations were made and yet no infection resulted. Consequently, relative humidity is unlikely to be the factor limiting black knot infections to approximately the month of May.

Amount and Type of Inoculum

So far as the infection experiments are concerned an abundance of fresh inoculum was always placed on the host tissues when the latter were inoculated. In nature it has been proved that at least from early spring until late fall an abundance of ascospores or conidia are available (7). Even during the winter chlamydospores are probably present in fair

abundance (*9*). Inoculum then cannot be the factor limiting infection to a short period of the year.

Condition of the Host.

In the Niagara peninsula the host is at the height of its activity during May and in some years also during the early part of June. During this time the tissues of current season twigs are succulent and immature. Under conditions prevailing in a plum orchard receiving the usual amount of cultivation, linear growth of current season twigs proceeds at a progressively slower rate from the latter part of June on. Beginning sometime in June, therefore, there is a gradually decreasing supply of meristematic host tissue available for infection, and since it has been shown both in article III of this series and in the infection studies of the present article that nearly all knots originate on rapidly-growing current season tissues, it would appear that the condition of the host more than any other single factor limits infection by *D. morbosum* to the spring of the year. More evidence to support this contention will be submitted in the studies on the pathological histology of the host.

Though temperature and relative humidity are probably not the factors limiting black knot infection on *P. domestica* to a relatively short period in the spring of the year, these factors are probably most important in a consideration of the epidemiology of black knot. During a certain early stage in the ontogeny of a plum twig it appears to pass through a period when it is susceptible to black knot infection. As the twig matures the tissues appear to become resistant. Temperature or relative humidity or a combination of both can undoubtedly prolong or shorten this period of susceptibility. For example, cool, damp weather during May delays growth and thus renders the host susceptible for a long period. In addition, these factors may limit the possibility of the germination of the spores, thus affecting the epidemiology of the disease, but they do not limit infection to a short period, because in the course of their ontogeny all twigs pass through a susceptible stage which in the Niagara peninsula occurs during May and early June. By way of example the almost complete lack of infection in 1934 can most likely be ascribed to the exceptionally dry May, when the relative humidity averaged only 58%.

VARIETAL SUSCEPTIBILITY

A wide variety of both wild and cultivated species of Prunus are susceptible to black knot. In Ontario the disease has been observed on the following wild hosts: *Prunus americana* Marsh, *P. virginiana* L. and *P. pennsylvanica* L. In the United States *P. chicasa* Michx., *P. Besseyi* Bailey, *P. maritima* Wang., *P. demissa* (Nutt.) Walp., *P. serotina* Ehrb., *P. emarginata* Walp., *P. melanocarpa* (Nels) Rydb., *P. nigra* Aib., *P. padus* L., *P. pumila* L., *P. triloba* L., *P. umbellata* Ell., and *P. subcordata* have also been reported (*12*) to be susceptible.

Of the cultivated varieties of plums all appear to be more or less suscept ble to black knot. In the Niagara peninsula Reine Claude and Lombard varieties are highly susceptible, while other varieties show varying degrees of resistance. General statements, however, pertaining to the resistance or susceptibility of Prunus varieties over wide areas cannot be made because a variety may be susceptible in one district and may appear

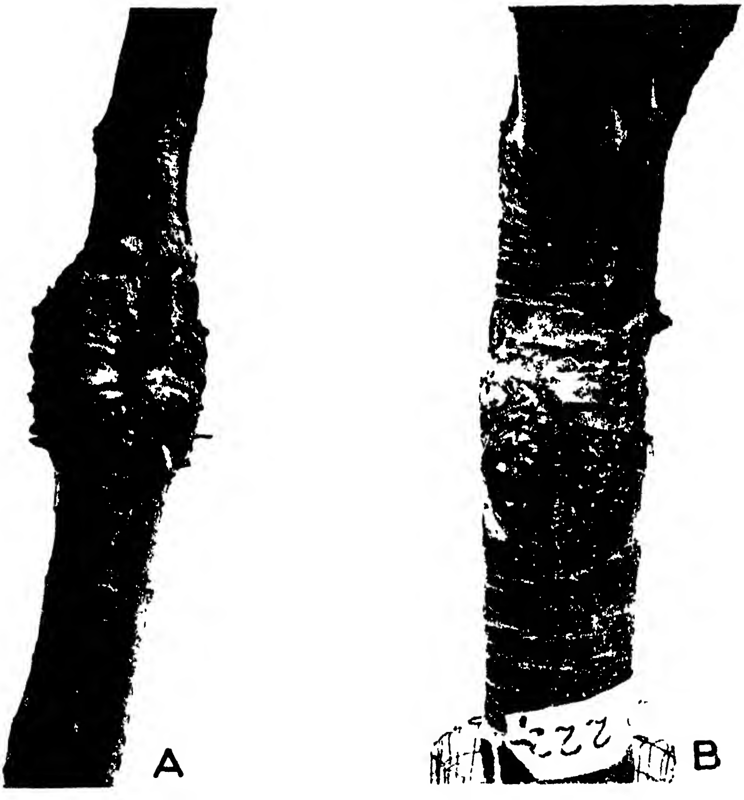

FIGURE 1. A. Swelling on large branch of *P. cerasus* 3 months after inoculation with conidia (*Hormodendrum* sp.) of *D. morbosum*. B. Swelling on trunk of *P. cerasus* produced as in A.

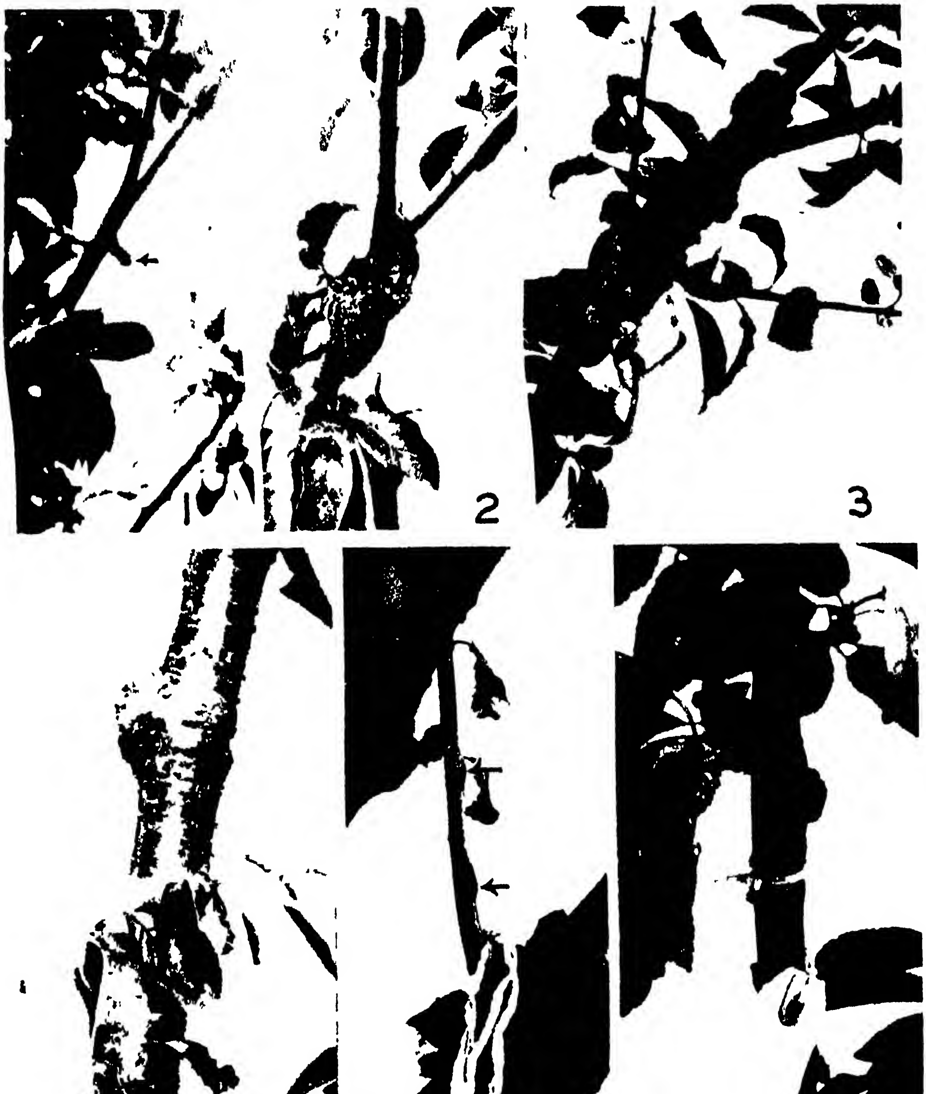

PLATE I. 1–3. Photographs of black knot produced by inoculating current season twig of *P. domestica* with conidia (*Hormodendrum*) of *D. morbosum*. 1. Knot 3½ months after inoculation, photo taken 25-8-32. 2. Knot one year older, photo taken 20-8-33. 3. Knot 2 years and 3 months after inoculation, photo taken 24-8-34. 4. Swelling on large branch of sweet cherry produced as a result of inoculation with conidia of *Hormodendrum* sp. 5. Showing incipient stages of young knot on current season twig produced by inoculation with conidia using Keitt's method; photo taken approximately 3 months after inoculation (24-8-33). 6. Knot on *P. domestica* produced by "patch-grafting"; photo taken 4 months later (7-9-34).

PLATE II 1–5 Cross sections of twigs of *Prunus domestica* infected with *D. morbosum* 1 Showing increase in development of both xylem and tissues external to the cambium in infected portion of stem, arrows indicate aggregates of fungous hyphae, section cut 25 8 32, × 32 2 As in 1; note large lacunae in various parts of infected xylem Note infected medullary rays extending nearly to pith, × 32 3 and 5 Showing mycelium of *D morbosum* advancing in mature xylem during winter, note gum-filled trachea in 3 and intercellular nature of mycelium, sections cut 3 3 32, × 300 4 Showing separation of xylem bundles as result of medullary ray infection; section cut 16 9 31, × 70.

PLATE III. 1-6 Sections of normal and diseased tissues of *Prunus domestica*. 1. Longitudinal section at border of infected medullary ray; note bending of mature xylem elements and aggregation of hyphal strands; section cut 17 9 32, × 300 2 Longitudinal section showing mycelium in mature xylem tissues in winter, section cut 5 3 32; × 300 3 Tangential section showing normal multiseriate medullary rays at left and tremendous increase in size of infected ray; note black aggregates of hyphae interspersed in parenchyma; section cut 17 5 32, × 70. 4. Cross section of normal twig 2 mm. from visible knot; no mycelium present; section cut 7 6 32; × 70. 5. Cross section showing infection of medullary rays nearly to pith; section cut 25 8 32; × 70. 6 Section through infected cortex showing numerous aggregates of hyphae; section cut 20 4 32; × 30.

to be resistant in another district. For instance, the Montmorency variety of sour cherry has not been observed to be attacked by black knot in the Niagara peninsula, while on the other hand, this variety is attacked most severely in the Georgian Bay district. Likewise *P. serotina* Ehrb., a common variety in the Georgian Bay district, has never been observed to be attacked by black knot in that region, while Halsted (*4*) reports *P. serotina* to be highly susceptible in New Jersey. Examinations of sour cherries and plums growing adjacent to each other in the Niagara peninsula have frequently showed the plums to be affected with knot while the sour cherries were not observed to be attacked.

The observations recorded above would seem to indicate the existence of physiologic forms of *D. morbosum* not all of which are present in certain districts.

PATHOLOGICAL HISTOLOGY

Since, as stated above, Stewart (*13*) has already made a major contribution regarding the anatomy of black knots this phase will be dealt with in detail only in so far as necessary to consider certain phases and features of the pathological histology which Stewart did not investigate.

For this study fresh materials were utilized in all cases. Both healthy twigs and knots in all developmental stages ranging from freshly-inoculated twigs and scarcely-visible swellings to mature knots several years old were sectioned with a sliding microtome, stained in cotton blue and mounted in lacto-phenol. Sections were subjected at different times to preliminary microchemical tests the results of which appear incidentally in the following paragraphs.

The examination of twigs freshly-inoculated both in the laboratory and outdoors on *Prunus domestica* showed that while many of the spores germinated and penetrated the cuticle and sometimes several cell layers deeper, the majority appeared to develop no further. The germ tubes of many tapered sharply to a point and gradually disintegrated. Sections of branches one or more years old inoculated with conidia of *D. morbosum* showed in many cases that the conidia germinated and penetrated the periderm intercellularly to a maximum depth of approximately seven cell layers (Figure 2, C). It was concluded from these sections that the presence of numerous layers of periderm which cover branches one or more years old, with the exception (noted by Lodeman (*10*)) of small areas at the nodes tends to preclude infection by the black knot organism in such twigs.

Although the mycelium of the pathogen was always present in the cambial regions in small visible knots its passage through the intervening cortical tissues in the earlier stages of infection was never actually observed. This may be accounted for by the small proportion of successful infections resulting from penetration. Soon after the cambial region in current-season twigs is reached by the mycelium, hypertrophy and hyperplasia of the host tissues begin, and since the earliest visible swellings induced by infection have been observed on or close to August 15, probably between two and three months elapse until the organism induces anatomical changes in the cambial region sufficient to be visible externally. Sections of these incipient knots always revealed the presence of the mycelium of the fungus

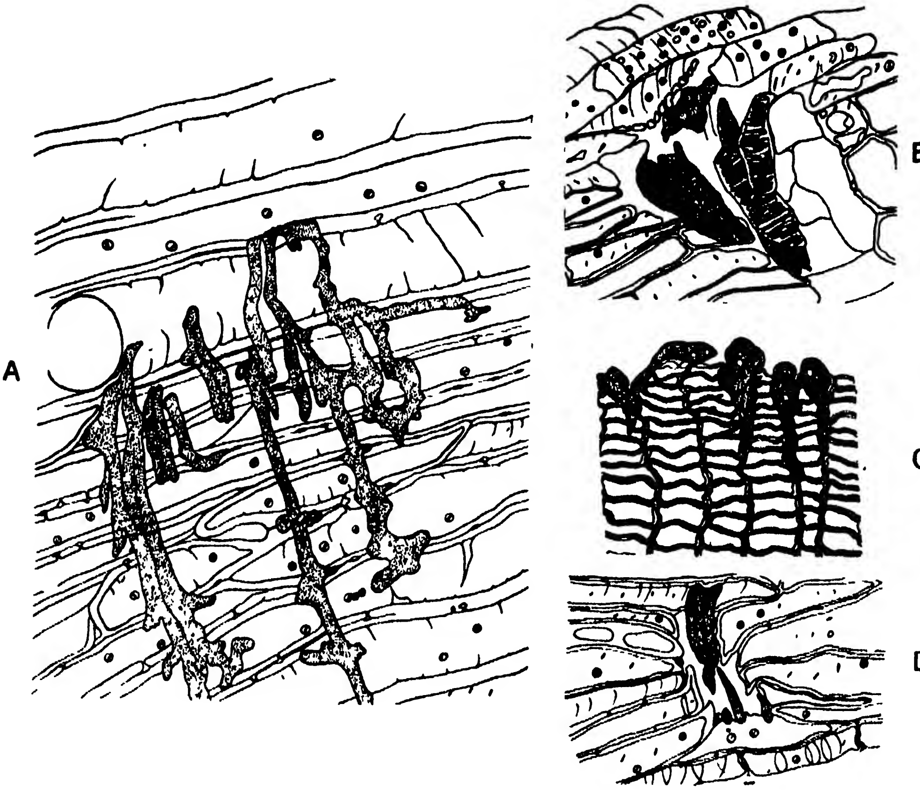

FIGURE 2 - A. Showing mycelium of *D. morbosum* penetrating intercellularly, xylem tissues adjacent to infected medullary ray; note character of mycelium and method of progress; drawing from section cut 14 12 32; × 350. B. Showing mycelium of *D. morbosum* near end of infected medullary ray; note scalariform tracheids, the formation of which was induced by the pathogen; × 250. C. Long section of bark of 2-yr. old branch of *P. domestica* showing conidia which have germinated and penetrated the periderm intercellularly; traced from photo micrograph of section cut 15 6 31; × 500. D. As in B; × 250; note distortion of xylem elements.

in the medullary rays and frequently also in the cambial and cortical tissues. Hypertrophy and hyperplasia of host cells was most apparent in the vicinity of these medullary rays. The hyphal strands of the fungus in infections on current-season twigs have been frequently observed in the ray tissues nearly as deep as the pith (Plate II, 1 and 2) (Plate III, 5) but little advance in a radial direction was indicated after the ends of the rays opening into the cambium were invaded. Normal medullary rays in twigs of *P. domestica* are usually multiseriate and as soon as invasion of these rays occurs in the cambial region instead of forming the usual proportion of xylem elements and ray tracheids the cambium produces a relatively large number of parenchyma cells which are also many times their usual size (Plate III, 3). As time progresses these infected rays become so wide in the cambial region that finally the cambium separates and the component cells and groups of cells become displaced outwardly into the cortical tissues. In cross sections the mycelium of *D. morbosum* which

is always present in phalangial groups of hyphal strands (Plate II, 1, 2 and 4) (Plate III, 6) is observed to occupy a central position in infected rays (Plate II, 1 and 4). After the cambium is broken these strands in many cases extend unbroken from regions near the pith to the outer cortical tissues. Frequently only several rays on one side of the twig become infected. Since these widen out rapidly the twig soon becomes swollen and distorted on the infected side (Plate II, 1 and 2). Slow invasion of normal xylem and cortical tissues by the pathogen begins during the fall of the first season of infection. In these tissues as in all other host tissues the mycelium of the knot organism is intercellular and as it advances it pushes to either side the normal elements which are frequently much distorted as a result (Figure 2, A, B and D). The advancing tips of the mycelium in these cases are very characteristic in appearance, appearing almost plasmodial (Plate II, 3 and 5) (Plate III, 1 and 2).

In infected medullary rays the effect of the pathogen in stimulating cell development has frequently been observed at a distance of several cells from the mycelium but in no instance has dying of either the fungous mycelium or the adjacent host cells been observed during the season of infection. Microchemical tests have indicated the absence of starch from all infected medullary ray tissue at times when starch is present in corresponding normal rays. While normal rays possess a considerable number of cells with lignified walls corresponding tests of infected rays indicated a complete absence of lignin from all elements with the exception of the scalariform tracheids formed adjacent to the mycelium (Figure 2, B).

Numerous sections of knots of all ages have shown that not until after the hyphae of *D. morbosum* and the cells of its host have been in intimate contact for a period of approximately six or seven months does either host or parasite display any definite ill-effect as a result of the presence of the other. Sections, however, of knots on twigs less than one year old, made in January, February or later, indicate a gradual yellowing of the mycelium of the fungus accompanied by a browning of host cells in contact or nearby. Frequently also, nearby tracheae gradually became filled with gum (Plate II, 3). By April or May large gum pockets occasionally developed in the older infected host tissues (Plate II, 2) due to the dissolution of the parenchyma of the affected medullary rays. These were accompanied by a degeneration of the adjacent fungous mycelium. At this time in some instances mature perithecia were present on the exterior of such areas and in other cases an abundance of conidia were beginning to develop. Sections of secondary knots on branches more than one year old, where invasion had occurred as a result of the advance of the mycelium during the winter from the boundary of the old knot into normal tissues beyond, showed the same relation between host and parasite as mentioned above for primary knots on younger wood. In the meantime, subsequent to perithecial formation the tissues of the primary knot died.

Sections of both knots and adjacent normal twigs showed that during the summer months when the host is growing rapidly the mycelium of *D. morbosum* could not be found at a distance of even 2 mm. from the visible knot (Plate III, 4). Beginning with the advent of the dormant season, however, and continuing throughout the winter months the hyphae

of the fungus were found at increasing distances up to approximately three inches beyond the boundary of the visible knot. All areas of the stem invaded by the mycelium during the winter increased rapidly in size during May and began producing an abundance of conidia in June.

CONTROL EXPERIMENTS

The results of experiments in control up until 1932 have already been published (7). Since that time, however, spraying experiments have been continued with certain modifications of the original schedule. In blocks F, G and H (see (7) p. 584) consisting of 32 mature trees, Lombard variety, the most successful control experienced to date (average 96%, 2 years) was obtained by an application of lime sulphur 1 : 50 when the trees were in full bloom, in addition to the delayed dormant (1 : 8 lime sulphur) and the "shucks" spray (1 : 50 lime sulphur).

This improvement in control can be directly ascribed to the additional protection which the spray application at "full bloom" gave to the trees. It has already been determined that ascospores may be discharged under favourable temperature and moisture conditions at any period of the host development before buds burst until early June at which time all "shucks" have fallen. During the above-mentioned period growth is very rapid and newly-formed tissues being unprotected by the fungicide are exposed to infection. Therefore, if black knot is very severe in a plum orchard it would appear that a spray application when the trees are in full bloom in addition to the "delayed dormant" and "shuck" applications will give ample protection from the disease.

DISCUSSION

In this final article dealing with investigations on black knot certain additional information regarding the infection capabilities of *D. morbosum* and the changes induced in the host by this pathogen has been submitted. The progress of the disease has been carefully followed from the time when minute swellings representing incipient infections appeared three to four months after inoculation until the pathogen produced perithecia one or more years later. It was shown in article III of this series that more than 95% of black knots originated on current season wood. The results of infection experiments reported in the present paper confirm this finding. Although branches of *Prunus domestica* of all ages were inoculated with both ascospores and conidia of *D. morbosum* with a single exception typical knots developed on current season twigs only. Previous observations that nearly all natural infections can be distinguished in the fall of the year of infection have also been confirmed by the present studies. The time required by the pathogen to complete its life cycle varies. Knots which produced conidia during the fall of the year of infection in many cases produced perithecia the following winter, thus completing the life cycle of the pathogen within a year. On the other hand, knots which did not produce conidia until the following spring produced them in greater abundance than did the previous type of knot and perithecia did not appear until the second winter after infection.

Although infection experiments were conducted throughout the year only those made during May and early June gave positive results. While the period of susceptibility to infection in nature is possibly more extended

than this, nevertheless, all evidence indicates that the period during which infection can take place is very limited. The conclusion was reached that though temperature, relative humidity and amount and type of inoculum are important factors in the epidemiology of black knot, nevertheless, the condition of the host is the outstanding factor which limits infection to a relatively short period during the early part of the growing season. In the latter respect *D. morbosum* is analogous in its pathogenicity to *Taphrina deformans* (Fcl.) Tul., which as Fitzpatrick (*2*) has indicated is capable of infecting the immature leaf tissues of *Prunus persica* only during a very limited period. *D. morbosum*, on the other hand differs markedly in its pathogenicity from certain species of *Valsa* which have been found by Willison[4] of this laboratory to be capable of infecting *P. persica* only after the host is in a dormant condition.

A study of the pathological histology of the host revealed not only a strik ng hypertrophy and hyperplasia induced by the pathogen but also a specific and interesting relation between pathogen and host. *D. morbosum* apparently belongs to that group of pathogenic organisms which, displaying a high type of parasitism, live in intimate contact with their hosts for relatively long periods (usually six to eight months in the case of *D. morbosum*) with no apparent killing of either parasite or host tissue. In this respect *D. morbosum* would seem to resemble *T. deformans* and even the rust and smut fungi. The fact that *D. morbosum* is difficult to establish in culture when either ascospores or knot tissues in certain stages of development are used as sources of isolation also indicates a high type of parasitism.

In this the final paper of a series in connection with an extended study of black knot it would seem necessary to summarize the salient features in the life history of an organism which displays a more or less unique type of parasitism. Knots may be initiated in the spring or early summer by ascospores, conidia or possibly by chlamydospores. After three to four months these knots usually become visible as small swellings. Conidia may or may not be produced on the surface of the swollen host tissues in the fall. During the first season a *Coniothyrium* sp. invariably becomes associated with the pathogen. If conidia are produced by the pathogen during the fall, perithecia develop normally during the subsequent winter except in cases where the stroma has been parasitized by *Cephalothecium roseum* in which case the perithecial initials have been destroyed.

Secondary knots may arise as the result of mycelial invasion during the dormant season of healthy tissues beyond the borders of knots already formed. In the spring conidia are produced in great abundance on the surface of both primary and secondary knots which have not previously fruited. During midsummer the stroma of *D. morbosum* on almost all knots becomes parasitized by *C. roseum* and frequently also by numerous other fungi. During the winter perithecia of *D. morbosum* are produced on the majority of knots which have produced conidia during the summer. Knot tissues always die after having produced perithecia or after having been parasitized by other fungi. The above sequence of events continues until such time as the branch is finally girdled by the pathogen which also dies at that time.

[4] Willison, R. S. Unpublished data.

From the standpoint of control the investigations of the fundamental phases of the black knot problem have emphasized the fact that this disease is ocmparatively easy to control provided that the actively-growing tissues of the host are adequately protected with a fungicide during the relatively short critical period of infection. The formation of secondary knots can be prevented by the excision of primary ones during the growing season in which they are first observed.

In concluding it should be stated that there are many important facts regarding the black knot disease yet to be discovered. For example, a study of the infection capabilities of the pathogen on hosts more susceptible than *P. domestica* should yield especially interesting and valuable information regarding possible physiologic specialization.

SUMMARY

1. Various methods of inoculation of twigs and branches of plums and cherries with ascospores, conidia and mycelium of *Dibotryon morbosum* (Sch.) T. & S., are enumerated.

2. Only one knot resulted from the inoculation of branches more than one year old with diseased host tissue.

3. The majority of artifically-produced knots developed only on current season twigs inoculated with aqueous suspensions of either ascospores of *D. morbosum* or conidia of *Hormodendrum* sp., the imperfect stage.

4. In the aggregate only 3% of the inoculations using ascospores or conidia of *D. morbosum* gave positive results. Though inoculations were made throughout the year 84% of the knots produced resulted from inoculation during May. Twenty-six per cent infection was obtained in May.

5. Three knots were produced on old branches of *P. domestica* by "patch grafting" portions of unswollen host tissue taken from just beyond the border of knots onto healthy branches.

6. All artificially-produced knots were visible during the fall of the year of infection and many produced conidia of *Hormodendrum* sp. during the fall, and perithecia of *D. morbosum* during the following winter and spring, thus completing the life cycle of the pathogen within a year.

7. Though relative humidity and temperature are probably the most important factors governing the epidemiology of black knot, undoubtedly the condition of the host is responsible for the limitation of infection to a relatively short period in the early growing season.

8. The susceptibility of certain wild and cultivated species of Prunus to *D. morbosum* is discussed.

9. A study of the pathological histology of the host was made. Ascospores and conidia of *D. morbosum* germinate on the surface of healthy plum twigs and under favourable conditions mycelium reaches the cambium which is stimulated to produce abnormally large quantities of both xylem and phloem.

10. The pathogen is usually present in host tissues as compound phalangial strands of hyphae, chiefly radial and always intercellular. In the vicinity of invaded medullary rays the fungus induces an increase both in number and size of the parenchyma cells, and instead of the normal xylem elements scalariform tracheids are produced, frequently in contact with the mycelium.

11. After the growing season the fungus advances through normal xylem tissues and though it distorts the elements causes no visible hypertrophy during the winter.

12. *D. morbosum* exhibits a high type of parasitism, for host and parasite are capable of living in intimate contact with each other for approximately six or seven months before displaying any mutual ill effect.

13. Recent control experiments have indicated that excellent control of black knot can be obtained by an additional spray application of lime sulphur (1 : 50) during "full bloom" as well as the previously-recommended "delayed dormant" and "shuck" applications.

ACKNOWLEDGMENT

Thanks are due Dr. G. H. Berkeley for many helpful suggestions offered at various times during the period of investigation.

REFERENCES

1. Farlow, W. G. Black knot. Bull. Bussey Inst. *24* 440-453. 1876.
2. Fitzpatrick, R. E. The life history and parasitism of *Taphrina deformans*. Sci. Agr. *14* · 305-326. 1934
3. Gilbert, E. M. Fungus-host relationship in black knot Phytopathology *3* : 246-247. 1913
4. Halsted, B D. Destroy the black knot of plum and cherry. An appeal. N.J. Agr. Exp Sta Bull *78* . 1-14. 1891.
5. Humphrey, J. E. The black knot of the plum. Mass (Hatch) Agr. Exp. Sta. Rept. *10* · 235-238. 1893.
6. Keitt, G. W. Peach scab and its control. U S D.A. Bull 395. 1917.
7. Koch, L. W. Investigations on the black knot of plums and cherries. I. Development and discharge of spores and experiments in control. Sci. Agr. *13* : 576-590. 1933.
8. ————. Investigations on the black knot of plums and cherries, II. The occurrence and significance of certain fungi found in association with *D. morbosum* (Sch.) T. & S. Sci. Agr. *15* · 80-95. 1934.
9. ————. Studies on the overwintering of certain fungi parasitic and saprophytic on fruit trees. Can Jour Research *11* : 190-206. 1934.
10. Lodeman, E G. Black knot of plums and cherries, and methods of treatment. Cornell Univ Agr. Exp. Sta. Bull 81, 637-655 1894.
11. Roach, W. A. Budding and grafting razors. Gardeners' Chronicle, March 24, 1934.
12. Seymour, A. B. Host index of the fungi of North America. Harvard University Press, p. 396. 1929.
13. Stewart, A., Some observations on the anatomy and other features of the black knot. Amer. Jour. Bot. *1* . 112-126. 1914.

Résumé

RECHERCHE SUR LE NŒUD NOIR (BLACK KNOT) DES PRUNIERS ET DES CERISIERS. L. W. Koch, Laboratoire fédéral de pathologie végétale, St. Catharines, Ont.

L'auteur énumère différents modes d'inoculation des rameaux et des branches de pruniers et de cerisiers avec des ascospores, des conidies et du mycélium de *Dibotryon morbosum* (Sch.) T. & S. L'inoculation, avec le tissus d'hôtes malades, de branches qui avaient plus d'un an, a provoqué l'apparition d'un seul nœud. La majorité des nœuds artificiellement produits ne se sont développés que sur des rameaux de la saison courante, inoculés de suspensions aqueuses d'ascospores de *D. morbosum* ou de conidies de l'espèce *Hormodendrum*, la phase imparfaite. Au total, seulement 3% des inoculations dans lesquelles on s'était servi d'ascospores ou de conidies de *D. morbosum* ont donné des résultats positifs. Quoique les inoculations aient été faites toute l'année, 84% des nœuds produits provenaient des inoculations faites en mai. Une infection de 26 pour cent a été obtenue en mai. Trois nœuds ont été produits sur de vieilles branches de *P. domestica* par le greffage en plaque, sur des branches saines, de parties non gonflées du tissu de l'hôte, prises juste au-delà de la bordure des nœuds, Tous les nœuds artificiellement produits étaient visibles pendant l'automne de l'année de l'infection et plusieurs ont produit des conidies de l'espèce *Hormodendrum* au cours de l'automne, et des périthécies de *D. morbosum* au cours de l'hiver et du printemps suivants, complétant ainsi le cycle évolutif du pathogène en une année. Quoique l'humidité relative et la température soient peut-être les facteurs les plus importants dans l'épidémiologie du nœud noir, il est évident que l'état de l'hôte est la cause de la limitation de l'infection à une période relativement courte, au commencement de la saison de végétation. La sensibilité de certaines espèces sauvages et cultivées de *Prunus* à *D. morbosum* est discutée. Une étude de l'histologie pathologique de l'hôte a été faite. Les ascospores et les conidies de *D. morbosum* germent à la surface de rameaux sains de pruniers; dans des conditions favorables, le mycélium atteint le cambium où il stimule la production de quantités anormales de xylème et de phloem. Dans les tissus de l'hôte, le pathogène est généralement présent sous forme d'hyphes phalangiennes, principalement radiales et toujours intercellulaires. Dans le voisinage des rayons médullaires envahis, le champignon provoque une augmentation du nombre et de la grosseur des cellules de parenchyme, et au lieu des éléments normaux de xyulème il se forme des trachéides scalariformes, fréquemment en contact avec le mycélium. Après la saison de végétation, le champignon pénètre à travers les tissus normaux de xylème et en dérange les éléments sans causer d'hypertrophie visible pendant l'hiver. Le *D. morbosum* exhibe un haut degré de parasitisme, car l'hôte et le parasite peuvent vivre en contact intime l'un avec l'autre pendant environ six ou sept mois sans manifester de mauvais effets mutuels. Il a été démontré par des expériences récentes que l'on peut fort bien prévenir le nœud noir par une pulvérisation supplémentaire de chaux soufrée (1:50) pendant la période de pleine floraison, ainsi que les applications déjà recommandées "dormantes retardée" et des "pétales".

EXPERIMENTS ON THE CONTROL OF CEREAL SMUTS BY SEED TREATMENT[1]

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Many of the varieties of wheat, oats, and barley grown in Canada are susceptible to smut. Accurate estimates of losses from smut diseases are difficult to obtain, but for the period 1920-1923 the average annual loss in this country was placed at $12,831,000. It is probable that much of the seed grain used during this period was treated before being sown. Had seed treatment of some kind not been practised the losses occasioned by the smut fungi would have been even more severe. It is equally evident that great possibilities still exist of reducing smut losses through improvements in seed treatments, and by the introduction of suitable smut-resistant varieties.

The ideal seed disinfectant should be effective, relatively cheap, easily applied, and yet not cause seed injury. It would be possible to draw up a long list of substances which are extremely toxic to smut spores, but for certain reasons most of them would be of little use for treating seed grain.

Until about 1896, copper sulphate, commonly known as bluestone, was probably the most widely used of all seed disinfectants. Formalin was then introduced, and it soon became the standard treatment for bunt of wheat, covered smut of barley, and the smuts of oats. In recent years copper and mercury dusts have come into general use for seed-treating purposes. Such substances are effective fungicides, are easily applied to the seed, and usually have a favourable effect on its germination.

Before any substance can be recommended to farmers for smut control it must be subjected to field tests under conditions suitable for natural smut infection. During the past five years tests of this kind have been made at the Dominion Rust Research Laboratory with no less than 37 substances. The results of some of these tests are not of sufficient importance to justify their publication. Others, obtained with some of the newer preparations now on sale in this or in other countries, may be of interest to agriculturists for purposes of reference. With this object in view these results have been summarized in the following tables, together with those from similar tests made with well-known seed disinfectants such as formalin and copper carbonate.

METHODS

The effectiveness of any smut treatment can be judged by comparing the percentage infection in treated and untreated rows of grain grown in the field. If infection in the untreated checks is relatively low it may not be possible to draw any conclusions from the results of the treatments. If, however, high infection has been secured in the untreated checks the results of the treatments tend to become significant.

[1] Contribution No. 429 from the Division of Botany, Experimental Farms Branch, Department of Agriculture, Ottawa.

[2] Senior Plant Pathologist, and Assistant Plant Pathologist respectively.

The conditions governing smut-infection have been studied by a number of workers, and those factors of greatest importance are now fairly well understood. As a result of this work it may be stated that, under field conditions, soil temperature, spore load, and the susceptibility of the host plant will to a great extent determine the degree of smut infection.

Temperature

Munerati (*5*, *6*) Faris (*2*), and others have shown that relatively low temperatures (10°–15° C.) favour bunt infection. For covered smut of oats the optimum temperature for infection was found by Reed and Faris (*7*) to be between 20° and 25° C., the exact point depending upon the moisture content of the soil and certain other factors. Faris (*1*) secured high infection with covered smut of barley at 10°, 15° and 20° C. when the soil moisture was kept at 40% or 50%. These results indicate that, under field conditions, early seeding of spring wheat, while the soil temperature is still low, should give high bunt infection, whereas a somewhat later seeding might be expected to give the best infection with the smuts of oats and covered smut of barley.

In practice it has been found that the date of the first seeding of spring wheat at Winnipeg is usually determined by the physical condition of the soil rather than by the soil temperature. In the period 1930–1934, during which the experiments referred to in this paper were conducted, the first date of seeding has fluctuated between April 21 in 1931, and April 29 in 1932. Perhaps the effect of date of seeding on smut infection may best be illustrated by some results obtained at Winnipeg in 1934 when smutted seed of wheat, oats, and barley was sown on five different dates, commencing April 28. On each of these dates four rod-rows were sown with each lot of smutted seed. The percentages of smut, recorded in Table 1, were arrived at by examining 200 heads in each of the four rows. It is evident from these results that spring wheat must be sown early if high bunt infection is to be obtained, whereas relatively late seeding may be expected to give good infection with the smuts of oats and covered smut of barley.

TABLE 1.—INFLUENCE OF THE DATE OF SEEDING ON SMUT INFECTION AT WINNIPEG IN 1934

Host plant	Smut	Per cent smut				
		Sown Apr. 28	Sown May 5	Sown May 14	Sown May 21	Sown June 2
Marquis wheat	*Tilletia laevis*	25.9	10 4	0 4	0.1	0
Kota wheat	*Tilletia tritici*	37 4	10 3	2.3	0 1	0
Trebi barley	*Ustilago hordei*	3 1	1 4	0 8	1 1	7 0
Abundance oats	*Ustilago avenae*	15 9	12 9	3 5	5.1	28 9
bundance oats	*Ustilago levis*	17 8	7 3	2 5	6.6	12.3

It should be pointed out that very little rain fell between May 5 and June 2 and, as a consequence, the soil became extremely dry. During this period, low soil moisture rather than unfavourable temperature was responsible for the poor infection on oats and barley. On June 5, 1.93 inches of rain fell, and good infection was secured in the rows of oats and barley sown on June 2, although wheat sown on the same date failed to become infected.

The soil temperature at this time must have been still favourable for infection by the smuts of oats and barley, although too high to permit infection by bunt of wheat.

Spore Load

The experiments of Heald and others (*3, 4*) have shown clearly that if other conditions are kept constant smut infection varies with the number of spores adhering to the seed, or as it is usually termed, the spore load. When a susceptible variety of wheat is grown under conditions suitable for infection, a spore load of 1–200 (1 gram of spores to 200 grams of seed) will give very nearly maximum infection. With this rate of smutting approximately 36,000 spores adhere to each grain of wheat.

In the experiments, the results of which are summarized in this paper, two spore loads were used for wheat, namely, 1–200, and 1–1000. The species of bunt used was *Tilletia tritici.* The spore load for barley was 1–200. Oats were smutted at the rate of 1–500, except in the years 1930 and 1931 when a spore load of 1–1000 was used. The inoculum used in all of the experiments was prepared by crushing smutted heads in a mortar and sifting the resulting material through a 200-mesh sieve. In this way smut spores free from all but a trace of debris were obtained. All of these spore loads provided heavier contaminations than are usually found on seed grain. Nevertheless, the infection secured in the untreated rows of barley was less than that frequently observed in farmers' fields.

Varieties

The varieties selected for the experiments were all known to be susceptible to the particular physiologic forms of smut used as inoculum. They were as follows: Kota and Mindum wheat, Trebi barley, Longfellow oats in 1930, and Abundance oats in the years 1931-34.

Treatments

The dust treatments were applied to the inoculated seed usually the day before seeding. The rates of application are given in the following tables in ounces per bushel.

The only wet treatments employed were those with formalin and Clarke's Wheat Protector. These treatments were made on the day of seeding. The formalin solution was made up to the usual concentration so as to contain one part by volume of commercial formalin in 320 parts of solution. This is equivalent to one pound of formalin in about 30 gallons of water. The "sprinkle" treatments were carried out by adding this solution to the seed at the rate of about three-quarters of a gallon per bushel, after which the seed was covered for 4 hours. In treating barley by the "immersion" method the seed was poured into the solution. This caused many of the smut spores to float to the surface. The liquid was then drained off, and the seed was removed from the vessel and covered for 4 hours. The solution containing Clarke's Wheat Protector was applied to the seed at the rate of three-quarters of a quart per bushel.

The results obtained with the following seed disinfectants are summarized in this paper:—

1. Formalin (Standard Chemical Co., Montreal, P.Q.).
2. Deloro copper carbonate, containing 20% copper (Deloro Chemical Co., Deloro, Ont.).

3. Mococo copper carbonate, containing 54% copper (Mountain Copper Co., San Francisco, Cal.).

4. Copper sulphate dust.

5. Monohydrated copper sulphate (Nichols Copper Co., New York).

6. Basic copper chloride, containing 20% copper (Canadian Industries Ltd., Montreal, P.Q.).

7. Basic copper chloride, containing 48% copper (Canadian Industries Ltd., Montreal, P.Q.).

8. Copper sulphocyanate, contaning 48% copper (Canadian Industries Ltd., Montreal, P.Q.).

9. Wackerite Dry Dusting Powder, containing 25% copper (Gesellschaft für elektrochemische Industrie, München, Germany).

10. Vitrioline, containing 17% copper (Usines Schloesing Frères and Cie., Marseilles, France).

11. Preparations manufactured by the Ansbacher Siegel Corp., New York: (1) Bordeaux dust, containing 12.5% copper. (2) Oxo Bordeaux dust containing 12.5% copper. (3) Colloidal Calomel. (4) Colloidal Yellow Oxide of Mercury.

12. Ceresan, containing 2% ethyl mercury chloride, (Bayer-Semesan Co., Wilmington, Del.).

13. New Improved Ceresan, containing 5% ethyl mercury phosphate (Bayer-Semesan Co., Wilmington, Del.).

14. Lunasan (Lunevale Products Ltd., Lancaster, Eng.).

15. Clarke's Wheat Protector (G. B. Clarke, Woburn Sands, Eng.).

16. Smuttox (Grasselli Chemical Co., Cleveland, Ohio).

Seeding and Smut Counts

The lots of treated and untreated seed were sown in the field in rod-rows replicated four times.

Smut infection was estimated about the time the grain began to ripen by examining 100 heads at two places in each row. Since four rows were sown with each lot of seed, the mean smut percentages recorded in the following tables are each based upon an examination of 800 heads.

RESULTS

Wheat

The results of the experiments on the control of bunt in artificially-smutted seed are summarized in Table 2.

The extent to which growing conditions may influence bunt infection is brought out by a comparison of the percentages of bunt occurring from year to year in plots of the same variety of wheat grown from untreated seed smutted with a uniform spore load. Soil temperature at the time of seed germination is probably the factor mainly responsible for these yearly fluctuations in bunt infection.

The infections obtained in the untreated rows provide also a good illustration of the effect of spore load on bunt infection. For the five-year period under consideration, a spore load of 1–1000 gave 20% infection on Kota and 38% on Mindum, whereas a 1–200 spore-load gave infections on these varieties of 58% and 64% respectively.

TABLE 2.—CONTROL OF BUNT (*Tilletia tritici*) IN KOTA AND MINDUM WHEAT BY SEED TREATMENT (ARTIFICIALLY-SMUTTED SEED; WINNIPEG, 1930–1934)

Treatment		Per cent bunt																			
		Kota										Mindum									
		Spore load 1–1000					Spore load 1–200					Spore load 1–1000					Spore load 1–200				
		1930	1931	1932	1933	1934	1930	1931	1932	1933	1934	1930	1931	1932	1933	1934	1930	1931	1932	1933	1934
Untreated		15.6	28.1	26.4	9.6	17.6	58.5	87.3	45.8	35.3	63.6	35.1	80.0	38.5	12.0	24.3	64.8	92.6	68.9	31.8	60.5
Formalin (1–320 sprinkle)		3.1	0	0.1	0	0	3.7	0.1	0.3	0	0	6.4	0.4	0.1	0.4	0	4.3	0.4	0.4	0	0.1
Copper carbonate (20% Cu.)	2 oz.	0.3	2.1		0.1	1.4	10.0	12.0		0.9	4.9	0.1	4.6		0.5	0.8	7.8	24.4		2.1	20.6
Copper carbonate (20% Cu.)	3 oz.	0.4	2.6				10.9	11.8				0.1	2.8				6.1	20.6			
Copper carbonate (54% Cu.)	2 oz.	1.0	0.9		0.1		9.9	6.1		0.5		0.9	0.3		0.1		13.5	23.4		0.4	
Copper carbonate (54% Cu.)	3 oz.	0.4	0.5	0.4			3.8	3.8	1.4			0.5	0.6	0.6			5.6	13.6	0.4		
Copper sulphate dust	2 oz.		2.6					5.3					4.5					17.8			
Copper sulphate dust (monohydrated)	2 oz.	1.8					8.4					0.3					2.6				
Basic copper chloride (20% Cu.)	2 oz.				0.8					3.3					0.1					4.4	
Basic copper chloride (20% Cu.)	3 oz.			0.3					7.8					3.0					8.9		
Basic copper chloride (48% Cu.)	2 oz.				0					2.4					0.1					2.8	
Basic copper chloride (48% Cu.)	3 oz.			0.5					2.4					0.5					2.1		
Copper sulphocyanate (48% Cu.)	2 oz.				1.6					12.5					2.5					15.8	
Wackenite Dry Dusting Powder	2 oz.					0.9					7.1					1.5					10.4
Vitrioline	2 oz.	1.4					16.8					0.3					18.9				
Vitrioline	3 oz.	0.6					12.6					0.6					17.4				
Bordeaux dust (12.5% Cu.)	2 oz.																11.0				
Oxo Bordeaux dust (12.5% Cu.)	2 oz.																14.9				
Colloidal calomel	2 oz.																58.9				
Colloidal yellow oxide of mercury	2 oz.																54.8				
Ceresan	2 oz.		0.9		0			7.4		0.1			4.1		0.1			15.3		0.1	
Ceresan	3 oz.		0.9	0.8				12.8	3.9				3.0	0.3				9.1	2.1		
New Improved Ceresan	½ oz.				0.1	0				0.4	1.6				0	0.1				0	3.9
Lunasan	2 oz.					0.6					5.8					1.0					14.0
Clarke's Wheat Protector					0					0.1					0					0.3	

By referring to the results in Table 2, it will be noticed that when bunt infection in the untreated plots was light, most of the treatments gave good control. With heavy infection in the untreated plots, however, control became more difficult, and differences in the effectiveness of treatments became apparent. In farm practice, wheat carrying a spore load of 1–200 would probably never be sown, but in experimental work heavy spore loads provide a useful method of evaluating the relative effectiveness of different seed-treating substances.

With few exceptions, the formalin treatment gave satisfactory results. But it must be borne in mind that the effectiveness of a liquid seed disinfectant such as formalin is determined not only by its fungicidal properties, but also by the manner in which it is applied. In the laboratory, where only a small quantity of grain has to be treated, it is a comparatively easy matter to standardize the treatment. On the farm, however, large quantities of grain must be treated at a busy time of the year, and the difficulties in the way of proper treatment are very great. For this reason, the results obtained with formalin in actual farm practice may fall far short of those secured in field-plot experiments.

Clarke's Wheat Protector, a liquid treatment, gave satisfactory results in the one year in which it was tested. However, it does not appear to have any particular advantage over the ordinary formalin treatment.

Many of the dusts when used with lightly-smutted seed reduced the bunt to one per cent or less, but they were not so effective when used with heavily-smutted seed.

In the tests conducted in 1933 and 1934 with New Improved Ceresan, this dust, applied at the rate of only ½ oz. per bushel, gave uniformly good bunt control, even when the seed was heavily smutted. It is a matter of considerable interest that such a light application of dust should protect the seed against bunt infection. Seed grain to which dust has been applied

Table 3.—Control of covered smut of Trebi barley by seed treatment (artificially-smutted seed; Winnipeg, 1931-1934)

Treatment		Per cent smut			
		1931	1932	1933	1934
Untreated		6.1	17.8	7.5	6.5
Formalin (1–320 sprinkle)		0	2.3	0.6	0
Formalin (1–320 immersion)		0	0	0.1	
Smuttox	3 oz.	4.1			
Copper carbonate (20% Cu.)	2 oz.	2.6			
Copper carbonate (20% Cu.)	3 oz.	1.4		8.4	
Copper carbonate (54% Cu.)	2 oz.	1.9			
Copper carbonate (54% Cu.)	3 oz.	1.9	9.3		
Basic copper chloride (20% Cu.)	2 oz.		16.3		
Basic copper chloride (20% Cu.)	3 oz.		13.1	8.1	
Basic copper chloride (48% Cu.)	2 oz.		4.6		
Basic copper chloride (48% Cu.)	3 oz.		5.6	1.3	
Copper sulphocyanate (48% Cu.)	3 oz.			9.6	
Wackerite Dry Dusting Powder	2 oz.				1.3
Ceresan	3 oz.	0.1	0.1	0.1	
New Improved Ceresan	½ oz.			0	0
Lunasan	2 oz.				0

at the rate of from 2 to 3 ozs. per bushel is unpleasant to handle, and under certain conditions may cause clogging of the drill. These objections are not met with in dusts which are effective when applied in relatively small amounts.

Barley

The results of experiments with covered smut of barley are summarized in Table 3. This smut was almost eliminated by immersing the seed in a solution of formalin. In 1931 naturally-smutted seed of barley containing many smut balls was treated in the same way. The plot grown from the treated seed was free from smut, whereas 9.1% smut was present in the plot grown from the untreated seed. The dust treatments with Ceresan, New Improved Ceresan, and Lunasan, reported in Table 3, gave equally good results, but the copper dusts proved to be unsatisfactory.

Oats

With the exception of Smuttox, a formalin-containing dust, all of the substances tested for the control of the oat smuts gave satisfactory results. By referring to the data given in Table 4 it will be evident that seed treatment controls loose smut as well as covered smut.

TABLE 4—CONTROL OF THE SMUTS OF OATS BY SEED TREATMENT (ARTIFICIALLY-SMUTTED SEED; WINNIPEG, 1930–1934)

Treatment		Per cent smut							
		Loose smut			Covered smut				
		1930	1931	1932	1930	1931	1932	1933	1934
Untreated		15.2	17.0	29.8	26.2	38.4	29.3	4.5	2.1
Formalin (1–320 sprinkle)		2.4	0	0	2.9	0	0	0	0
Smuttox	3 oz	1.8	8.5		3.3	27.9			
Ceresan	3 oz.	0.1	1.3	0	1.0	1.6	0	0	
New Improved Ceresan	½ oz.							0	0.3
Lunasan	2 oz.								0

NOTE — In 1930 the tests were made with Longfellow oats, and in the remaining years with Abundance.

In other trials, not reported in Table 4, copper dusts, such as copper carbonate and copper chloride, were found to be of little value for controlling the oat smuts. This finding corroborates the experience of other workers, that copper dusts do not effectively control the smuts of coarse grains.

In the discussion of bunt of wheat, it was pointed out that under farm conditions the difficulties of properly applying the formalin treatment tended to impair its effectiveness. The same objection applies to the treatment of oats and barley with formalin. This view is supported by reports from farmers of heavy smut infection in fields of oats and barley grown from formalin-treated seed. As compared with liquid treatment, the dusting of grain is an extremely simple process. For this reason the general use of good dust disinfectants may be expected to reduce greatly losses from the smuts of oats and barley, as well as those from bunt of wheat.

Because of the light infections in the untreated plots in 1933 and 1934, the results of the tests with New Improved Ceresan, as given in

TABLE 5.—CONTROL OF SMUT OF OATS BY SEED TREATMENT (NATURALLY-SMUTTED SEED; WINNIPEG, 1933).

Treatment		Per cent smut	
		Lot 1	Lot 2
Untreated		23.5	30.8
Formalin (1–320 sprinkle)		0.1	0.6
Ceresan	3 oz.	0	0.3
New Improved Ceresan	½ oz.	1.6	0.1

Table 4, are not of great value. This dust was used in some other experiments made in 1933 with two lots of naturally-smutted oats sent to the laboratory by farmers. In these tests, the results of which are shown in Table 5, New Improved Ceresan, when applied at the rate of ½ oz. per bushel, gave satisfactory smut control.

SUMMARY

A brief reference is made to improvements which have been effected in seed disinfectants used for the control of cereal smuts. Organic mercury dusts, because of their effect veness and the ease with which they can be applied to seed, appear to be replacing liquid treatments and the copper dusts.

During the period 1930-1934, 37 preparations were tested in field experiments for the control of smut. The results obtained with 16 of these preparations are summarized in tables.

Formalin gave good control of bunt of wheat, covered smut of barley, and the smuts of oats. This treatment is relatively cheap, but it is more difficult to apply than the dust treatments, and under certain conditions may cause seed injury. The copper dusts are to be recommended only for treatment of wheat and hulless oats. In general, they gave good control of bunt when the seed was not too heavily contaminated with spores. New Improved Ceresan, an organic mercury dust, was effective in controlling bunt of wheat, covered smut of barley, and the smuts of oats. This dust, because of the light rate at which it is applied, should not cause clogging of drills. In certain experiments, the results of which are not recorded in this paper, seed treated with copper and mercury dusts gave a higher percentage of seedling emergence than untreated seed.

LITERATURE CITED

1. FARIS, J. A. Factors influencing the infection of *Hordeum sativum* by *Ustilago Hordei.* Amer. Journ. Bot. *11* : 189-214. 1924.
2. ———. Factors influencing the infection of wheat by *Tilletia tritici* and *Tilletia laevis.* Mycologia *16* : 259-282. 1924.
3. HEALD, F. D. The relation of spore load to the per cent of stinking smut appearing in the crop. Phytopath. *11* . 269-278. 1921.
4. ———, and L. W. BOYLE. Further notes on the relation of the spore load to the per cent of stinking smut appearing in the crop. Phytopath. *13* · 334-337. 1923.
5. MUNERATI, O. Osservazioni sulla recettivita del frumento per la carie. Atti. Accad. Lincei Cl. Sci. Fis. *V. 31* : 125-129. 1922.
6. ———. La basse temperature al momento della germinazione fanno sfuggire il grano all'attacco della carie? Atti. Accad. Lincei Cl. Sci. Fis. *V. 32* : 285-289, 1923.
7. REED, G. M. and J. A. FARIS. Influence of environmental factors on the infection of sorghum and oats by smuts. II. Experiments with the covered smut of oats and general considerations. Amer. Journ. Bot. *11* : 579-599. 1924.

Résumé

EXPÉRIENCES SUR LA POSSIBILITÉ DE PRÉVENIR LES CHARBONS DES CÉRÉALES PAR LE TRAITEMENT DE LA SEMENCE. W. F. Hanna et W. Popp, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

Les auteurs relatent sommairement les améliorations qui ont été apportées aux désinfectants employés sur la semence pour prévenir le charbon des céréales. En raison de leur utilité et de la facilité avec laquelle elles peuvent être appliquées, les poussières organiques de mercure paraissent devoir supplanter les traitements liquides et les poussières de cuivre. Pendant la période 1930-1934, il a été essayé 37 préparations dans des essais pratiques pour maîtriser le charbon. Les résultats donnés par 16 de ces préparations sont résumés en tableaux La formaline s'est montrée efficace contre la carie du blé, le charbon vêtu de l'orge et le charbon de l'avoine. Ce traitement est relativement bon marché, mais il s'applique plus difficilement que les poussières et il peut même abîmer la semence dans certaines conditions Les poussières de cuivre ne sont recommandées que pour le traitement du blé et de l'avoine nue. En général, elles ont bien maîtrisé la carie lorsque la semence n'était pas très contaminée de spores. Le nouveau Ceresan Amélioré, une poussière organique de mercure, a réussi à prévenir la carie du blé, le charbon vêtu de l'orge et le charbon de l'avoine. Cette poussière ne devrait pas boucher les tuyaux du semoir, car elle s'applique en faible quantité. Dans certaines expériences, dont les résultats ne sont pas enregistrés dans cet article, la semence traitée avec des poussières de cuivre et de mercure a donné un pourcentage plus considérable de plantules que la semence non traitée.

A STUDY OF THE PROTEIN REQUIREMENTS OF GROWING CHICKS[1]

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To grow chicks economically, it is essential that protein, a vital and expensive nutrient, be present in optimal amount. Since a study of the protein requirements involves certain aspects of avian metabolism as yet inadequately understood, the work reported here may be regarded in the light of a preliminary study only.

Nutritional workers have known for some years that equivalent amounts of protein from different sources do not have the same dietary value. Certain native proteins are known to be deficient in some essential amino acids and various tables of the biological value of proteins, based on feeding trials with mammals, have been elaborated. Many investigators in the field of avian protein requirements have almost wholly disregarded this aspect of the problem and have advocated protein levels for chick rations based on experiments in which a single type of protein was fed. Until such time as a purified diet, capable of satisfying the nutritive requirements of chicks in all factors, other than protein, is found, it is impossible to formulate absolute feeding values of proteins in avian nutrition. Experiments conducted in this laboratory have shown that a combination of proteins gave better growth and development than any single protein, and moreover that equivalent amounts of protein from either buttermilk powder, fish meal or meat meal did not give the same growth response. In view of these facts it seemed feasible to use a combination of proteins in this experiment rather than have results mitigated by some possible amino acid deficiency, or other, as yet unknown, factors.

Mussehl and Gish (*7*) reported that growth was progressively increased as the amount of animal protein was raised to 10 4% of the total ration. This required the addition of 19.5% of meat meal (53.5% protein). Carrick, Hauge and Prange (*1*) developed a ration which gave no better growth on increasing the level of meat meal (50% protein) above 19%. Holst (*4*) advocated a high protein content in rations for starting chicks and called attention to the fact that the amount of animal protein necessarily depends on the particular protein and other ingredients in the basal ration. Heuser and Norris (*3*) fed chicks on rations containing 20 9, 18.6, 16 8 and 15.2% of protein. During the first eight weeks growth ranged in order of protein content. Later, the same workers (*8*) fed rations containing 20 23, 17.93, 15.49 and 12.87% of protein, supplied by meat meal. The best growth, for the first eight weeks was obtained on the ration containing 20% protein. The paralleling of the growth curves after eight weeks with the lot receiving 15.5% protein suggested that such was the requirement for that period of growth. The efficiency of protein utilization decreased with advancing age. St. John, Carver, Halphrey, Miller and Cassell (*9*) fed rations containing 13.56, 14.43, 15.03, 16.06 and 17.17% protein, using skimmilk powder as their variable source.

[1] A contribution from the Nutritional Laboratory, Department of Poultry Husbandry. A part of this work formed the undergraduate thesis of one of the authors (J.D.M.) in fulfilment of the requirements for the degree of Bachelor of the Science of Agriculture (1932), the actual experiment being conducted in 1931.

The Ca : P ratio only varied from 2.55 : 1 to 2.13 : 1. The increase in protein levels resulted in improved growth.

It seemed evident that an investigation of the protein requirements of chicks, using a combination of protein sources was indicated. While this problem was under investigation and since its conclusion, four papers dealing with this problem have been published. Swift, Black, Voris and Funk (*10*) used a mixed protein supplement containing 75% dried buttermilk, 12.5% fish meal and 12 5% meat scrap. Their experiment was divided into four periods of four week's duration each. The rations in each of these periods varied slightly. The greatest gain for the sixteen weeks was made by the lot receiving 21.90, 21 21, 20.91 and 20.29% protein, respectively, in each of the periods. In the first four weeks the greatest gain was made by the lot receiving 22 9% protein, from four to eight weeks on 21 21%, from eight to twelve weeks on 17 31% and, from twelve to sixteen weeks on 14.74% protein. Carver, St. John, Aspinal and Flor (*2*) experimented with three levels of skimmilk powder. For the first ten weeks the most rapid growth was made on the ration containing 18% protein. Milne (*5*), using a mixed protein supplement, obtained the best growth with 23.3% protein. Morris, Thompson and Heller (*6*) obtained maximum growth with 17 to 20% crude protein, an increase to 24% giving no better growth.

EXPERIMENTAL

The experiment was conducted in the "Candee" section of the brooder house of the Poultry Department, Ontario Agricultural College. The rations were composed of the same ingredients in varying amounts. These basal mixtures were as follows:

Grain Mixture		*Protein Mixture*	
Ground Yellow Corn	100	Buttermilk Powder	100
Groung Durum Wheat	100	Fish Meal	70
Ground Barley	100		
Ground Oat Groats	100		

Mineral Mixture	
Bone Meal	2
Fine Oyster Shell	2
Fine Grit	2
Iodized Salt	1

The increasing levels of "animal protein" were added to the ration at the expense of the grain mixture, resulting in some loss of "vegetable protein", but an amount insignificant compared to the total protein of the ration, especially in view of the low biological value of this type of protein. It was obvious that the addition of protein increased the mineral content of the ration. The mineral content of all rations was equalized by decreasing the mineral supplement by an amount equal to the mineral content of the added protein, the ash content of the rations being constant at 6.3%. The Ca : P ratio varied from approximately 2.5 : 1 to 1.5 : 1 which is within the generally accepted range of 3 : 1 to 1 : 1 especially since 3% of cod liver oil was added to all rations. Green feed was supplied in the form of alfalfa leaf meal at a 4% level throughout.

The composition of the rations is given in Table. 1.

TABLE 1.—COMPOSITION OF DIETS

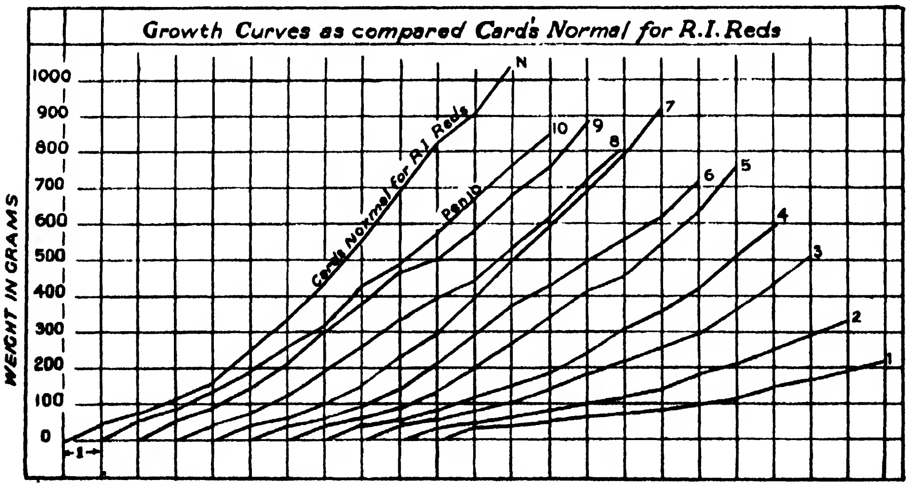
	Pens									
	1	2	3	4	5	6	7	8	9	10
	%	%	%	%	%	%	%	%	%	%
Grain mixture	88 8	86 0	83 1	80 3	77.4	74 6	69.7	60 2	50 7	41 1
Protein mixture	0 0	3 0	6.0	9 0	12 0	15 0	20 0	30 0	40 0	50 0
Mineral mixture	4 2	4 0	3 9	3 7	3 6	3 4	3 3	2 8	2 3	1 9
Alfalfa leaf meal	4 0	4 0	4 0	4 0	4 0	4 0	4 0	4 0	4 0	4.0
Cod liver oil	3.0	3 0	3 0	3 0	3 0	3.0	3 0	3 0	3.0	3 0
% Crude protein N = 6 25	11.6	12 7	13 7	14 4	15 3	16.3	19 0	22.7	26.4	30 0

From fifty to sixty, day-old, Barred Plymouth Rock chicks from the pedigree line of the College, hatched in a Petersime incubator, were used for each ration. The birds were weighed individually, to the nearest gram, weekly for twelve weeks. At the end of this period they were examined for sex, colour and texture of feathering, as well as the amount of feather development over the back and for head and leg development. Feed consumption was measured for three, four-week periods and a record of mortality was kept.

Influence of Protein on Growth

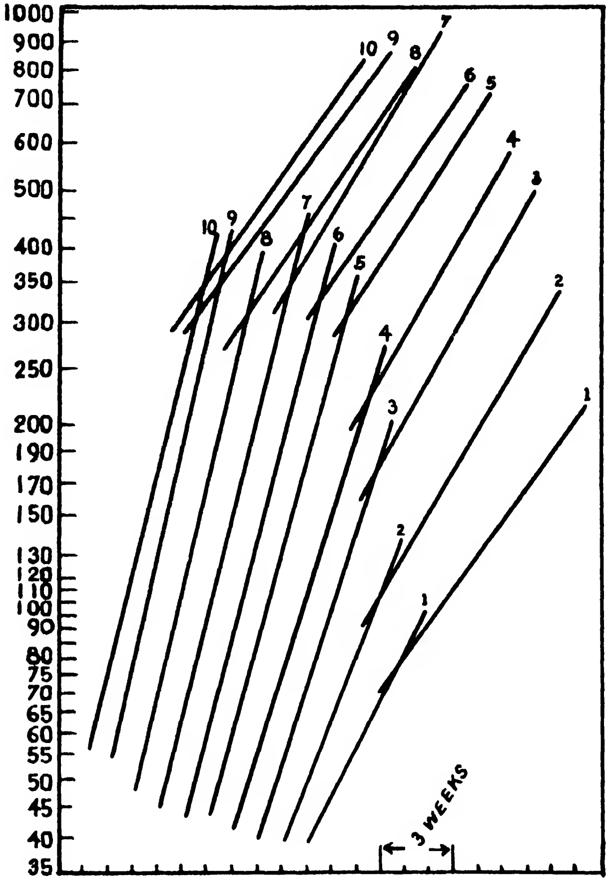
Growth curves compiled from the average weekly weights are shown in Graphs 1 and 2. The average weights of each pen by weeks is shown in Table 2.

This experiment was conducted before the importance of the vitamin B_2 complex for growth was extensively realized, together with the knowledge that commercial preparations of protein concentrates varied in their



GRAPH 1.—The influence of the protein content of the ration on the growth of chicks.

vitamin B_2 content. Although milk is an excellent source of this growth factor, it is possible that different growth responses might have been obtained if a constant source of this factor had been included in all rations. In other words, the increased growth obtained by increasing the protein mixture of buttermilk powder and fish meal, up to the optimum level, may not have been due entirely to protein *per se*, but may have been partially the result of increased vitamin B_2 in the increased amounts of the proteins, particularly the milk. However, this possibility does not invalidate the practical importance of the findings.



GRAPH 2. The influence of the protein content of the ration on the growth rate of chicks.

At the end of the first six weeks the greatest growth was shown by pens 8 and 9. The best growth throughout the entire period was made by pen 7. After the first six weeks pens 8, 9 and 10 grew at about the same rate. During the last two weeks pens 5, 6, 7, 8, 9 and 10 made about

TABLE 2 AVERAGE WEIGHTS (GRAMS) PER PEN PER WEEK

Age (Weeks)	1	2	3	4	5	6	7	8	9	10
1	39 3	39 4	41 0	41.0	43 6	43 6	45 1	48 0	55.1	55.7
2	46 8	50 3	56 9	57 2	65.6	61 8	64 9	75 8	87 8	84 9
3	58 1	85 8	76 6	83 4	92 4	95 3	105 1	122 8	144 5	136.4
4	70 8	86 2	108 2	120 4	137 9	143 7	156 2	191 1	209.6	190 7
5	80 6	104 5	147 6	153 6	200 9	210 2	233 5	260 8	304 2	261.1
6	89 3	121 1	188 8	188.6	270 2	295 1	294 2	336 3	383.2	338.3
7	103 1	145 7	218.1	241 5	338.5	374.3	390 1	391 7	469 1	429 1
8	120 5	188 8	260.7	315 8	414 9	427 7	494.5	440 6	500 1	487 7
9	151 1	212 6	295 1	360.6	455.6	497 1	596 2	533 2	582 0	572 5
10	170.1	253 1	364 1	422.5	542 4	566 3	693 2	615 8	679 8	667.4
11	191.4	295 1	433.1	511 7	634 3	618.2	792 6	725.9	755.5	764 2
12	218 6	335 4	513 2	592 3	759 3	723 4	925 6	808 4	879 3	847 8

the same growth rates. Pens 1 to 4 were retarded throughout the experiment. The fact that the growth of pen 10 slowly fell behind that of pens 7 and 9 shows that this ration probably contained an excess of protein, detrimental to growth, although the fact that this lot grew better than pen 8 would indicate some possible adjustment to a high protein intake.

These results indicate that during the first six weeks the protein requirement for the most rapid growth of chicks is high, being approximately 25%; from the sixth to tenth week the requirement would seem to be about 18 to 20% and after this period could probably be reduced to about 15%. The results would further indicate that the protein content of a chick mash, for use during the first ten or twelve weeks, should be about 19%. Since the birds fed on the diet containing 11.6% of protein did show some growth it is evident that the avian protein requirements for maintenance alone is less than this amount. The results are in general agreement with the conclusions of other investigators.

However, in view of other experiments to be reported later, in which excellent growth was obtained by the use of a ration containing 15.3% crude protein, it should be pointed out that the optimum protein level, using a particular type of ration as a basal, does not *a priori* indicate that such is the optimum level for all rations. Either the protein requirement is influenced by the other constituents of the diet, or, in such a ration as mentioned, a more proper blending of the proteins has been achieved. It is of interest to mention that this ration was formulated by a study of the intake of chicks given a choice of a variety of foods, that is, by cafeteria feeding. Such a ration, as well as having a lower protein content, does not contain the crude animal protein supplements, such as milk powder, fish meal or meat meal in the proportions commonly used.

It is possible, in addition, that the physical state of the ration may influence the digestibility of the ration and so effect the economy of the utilization of any individual component of the ration, such as protein. This cafeteria ration is not a finely ground mash but is coarser, due to the use of rolled or crushed rather than finely ground grains.

Efficiency of Food Utilization

The feed consumption was recorded for three four-week periods. The average food consumption per bird was calculated by dividing the total amount of feed eaten in the period by the number of birds alive in the pen at the end of the period, that is, charging the mortality against the diet.

The periodic feed consumption together with the gain per unit of feed is shown in Table 3.

During the first period the most efficient utilization of feed was made in general by the pens containing the greater amounts of protein. In the second and third periods the most efficient utilization was made in pen 7.

These results again confirm the findings that efficiency of food utilization decreases with advancing age, since in almost every case the gain per 100 grams of food eaten becomes progressively smaller.

In experiments of ths nature one factor is not taken into consideration —namely, that of allowing the birds more floor space with increase in size. A consideration of this factor might possibly make some changes in a study of food utilization.

TABLE 3.—FEED CONSUMPTION

—	Pens									
	1	2	3	4	5	6	7	8	9	10
1st 4 weeks—										
Total consumption	15890	13283	18160	12939	21338	15436	16798	26332	22700	19552
Average consumption	337 8	282 6	356 1	275 3	395 1	395 8	365 1	478 7	504 4	443.6
Consumption per 100 grams gain	482	327	329	228	286	275	233	303	241	232
Gain per 100 grams consumption	20 7	30 5	30 3	43 1	34 9	36 3	42 7	33 0	41 4	43.1
2nd 4 Weeks—										
Total consumption	13283	16798	27240	29283	45845	30074	40633	49713	42222	35185
Average consumption	332 1	399 9	555 8	681 0	898 9	812 8	944 9	937 9	981 9	902 1
Consumption per 100 grams gain	668	389	364	348	324	287	279	336	336	304
Gain per 100 grams consumed	14 6	25 6	27 4	28 6	30 8	34 8	35 8	29 4	29 7	32 8
3rd 4 Weeks—										
Total consumption	20657	32915	39044	41768	60382	44080	64595	54615	58112	70597
Average consumption	573 8	843 9	1055 2	1070 9	1312 6	1296 4	1584 0	1188 1	1417 3	2073.7
Consumption per 100 grams gain	584	575	417	387	316	438	298	323	373	575
Gain per 100 grams consumed	17 1	17 3	23 9	25 8	31 6	20 5	33 4	30 9	29 4	17.3

Influence of Protein on Mortality

The weekly mortality together with the per cent mortality for each pen is shown in Table 4.

TABLE 4.—MORTALITY

—	Weeks												Percent mortality
	1	2	3	4	5	6	7	8	9	10	11	12	
Ration 1	0	5	5	0	0	2	4	1	2	1	0	1	38 6
2	3	2	5	3	1	1	2	1	1	0	2	0	30 0
3	2	3	0	1	0	0	1	1	1	4	5	2	31 7
4	3	5	3	1	1	0	1	2	1	1	2	0	28 9
5	1	2	0	1	0	1	0	2	1	1	0	3	17 2
6	6	8	2	0	0	1	0	1	0	1	1	1	27 9
7	4	4	1	0	1	0	1	1	1	0	0	1	18 1
8	3	0	2	0	0	2	0	0	3	2	1	1	18 3
9	0	3	0	0	0	1	0	1	1	0	0	1	14.5
10	3	4	1	1	0	0	3	2	2	1	1	1	30.1

In calculating the per cent mortality the first week's mortality was disregarded, in order to avoid, in so far as possible, any death not strictly due to a dietary factor. However, some diets, used in experimental work in this laboratory have shown 100% mortality during the first week, indicating that mortality may be influenced by diet, in severe cases at least, during the first week.

The general trend of mortality indicates that the nearer the protein level approaches the optimum, other factors being equal, the lower the mortality. An excess protein content, as would be expected, raises the death rate.

FIGURE 1. A "blue" cockerel showing the effect on the barred feather pattern of excessive protein The males become lighter in colour as shown in Figures 1 to 3 inclusive. A similar condition results on low protein rations.

FIGURE 2 A "grey" cockerel, showing the effect of excessive protein in the ration on the barred feather pattern.

FIGURE 3 A "white" cockerel fed on the high-protein rations

FIGURE 4 A "dark" pullet, showing the darkening of the barred feather pattern due to high protein rations.

FIGURE 5. A "smutty" pullet, showing the indistinct character of the barred pattern on high protein rations.

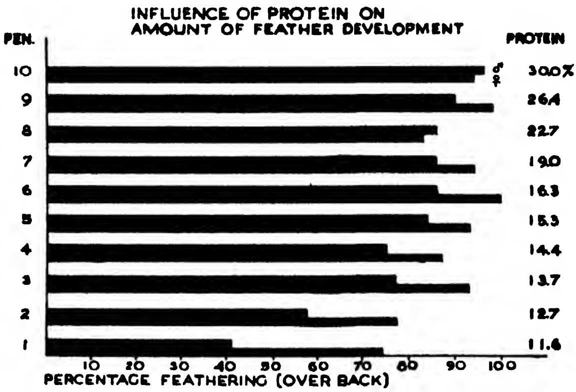
FIGURE 6. A "blue" pullet fed on a high protein ration. Note, not only the upset in the barred feather pattern, but also the "square" feather tips.

Influence of Proteins on Feathering

1. Amount of Feathering

The percentage of feathering over the back of each bird was estimated. Averages were calculated for the males and females in each group. These are shown in Chart 1.

CHART I



As will be seen there is a direct relationship between the amount of protein in the ration and the amount of feathering of the cockerels, the amount of feathering increasing with additional protein. In the case of the pullets this relationship is not so marked, although the birds fed on the lower protein levels are definitely retarded in feather development. On almost all diets the pullets showed more feather development than did the corresponding cockerels.

2. Colour and Barring of Feathers.

During the seventh to eighth week there was a tendency towards the "destruction" of the barred feather pattern in the plumage of the birds on the low and high protein diets. This may be an actual destruction, or an inhibition of, or some metabolic upset, disturbing the deposition of pigment. The results of this "destruction" was a change in colour of the feathers. The cockerels became bluish grey, blue and in a few cases almost white in colour. No explanation can be offered at the present time for this phenomenon. A few typical birds taken from various pens showing some of the colour variations are shown in the photographs.

The development of the barring was estimated for both sexes. These results are shown in Table 5.

TABLE 5 — INFLUENCE OF PROTEIN ON FEATHERING

Pen	Total feathering		Percentage barring	
	Males	Females	Males	Females
	%	%	%	%
1	41	74	46	83
2	58	77	83	85
3	77	93	54	96
4	75	87	91	94
5	84	93	92	100
6	86	100	90	60
7	86	94	81	66
8	86	83	50	60
9	90	98	94	45
10	96	94	56	44

It will be seen that the development of barring in the feathers of cockerels is due primarily to some factor other than dietary. In the case of pullets the development of barring would seem to definitely be associated with the diet. These results also suggest that the optimal protein requirement for growth is not the same as that for the development of the proper barring in pullets. A high protein content definitely upsets

this feather development. This aspect of the problem is of particular importance to breeders of exhibition birds, in which a proper blend must be made between growth and feather barring. It would seem from these results that this blend would not be easily obtained. Any change in colour of growing birds would indicate that the protein content of the ration was incorrect.

3. Texture and Contour of Feathers

In some cases the feather web approached the silky appearance of the feather fluff found on the lower shaft, giving the birds the so-called "silky appearance". Again this abnormality in feather development did not seem in cockerels to be definitely associated with the diet, although there is some relationship to both high and low protein levels. With pullet feathering this abnormality definitely developed on the two high protein rations, in pens 9 and 10 and on the low protein intake in pens 1 and 2.

FIGURE 7. Showing the typical "square" feather development on a ration with a high content of peas.

In connection with feather development, it might be of interest to point out that some birds on a high protein intake, grew feathers whose shape or contour, as well as texture, resembled the feathering of squabs, that is, having square ends. This type of feathering has also been developed on a ration containing a high content of ground peas (see Figure 7).

These dietary influences on feather development would not be so noticeable and in some cases would not occur if white birds were used. Most workers in this field have used White Leghorn chicks which would account for their failure to note these abnormalities.

The Influence of Protein on the Development of Slipped Tendons

Many investigators have associated the development of slipped tendons with the protein content of the ration, in most cases with an excess of this nutrient. Some have indicated that this condition is associated with the protein *per se*, others with an excess or unbalancing of the mineral content of the diet, caused by the excess protein. In this experiment the ash content of the ration was the same in all diets, which should prevent in so far as possible any excess or unbalancing of minerals, especially in view of the fact that the Ca : P ratio varied within normal limits.

During the fourth week one bird in Pen 3 and one in Pen 2 during the eighth week, developed slipped tendons. These were the only cases

on a low protein intake. In Pen 10 the first case of slipped tendons appeared at the end of the third week, two more developed at the end of the fifth week, one during the sixth week and two during the seventh week, making a total of six in all. The birds in this pen were the only ones of these receiving a high protein diet which showed this abnormality.

These results would indicate, in view of the few birds which developed slipped tendons, that this abnormality is associated with some factor other than the protein content of the diet. However, since it is in general the most rapidly growing birds, on any ration which seem predisposed to develop slipped tendons, the protein in a ration may be a contributary factor. It may be that the growing chick gains in weight so rapidly on a high protein intake, that muscular development advances ahead of bone formation, and hence the bones are unable to support the chick, the consequent bending of the bones allowing the tendons to slip to either side.

Influence of Protein on Head Development

During this experiment notes were made on the development and formation of the birds' heads, since "type of head" is a factor in estimating the constitution of the bird in relation primarily to vigour and egg production. Most of the birds receiving a low protein diet developed the condition known as "crow-head", characterized by a narrow skull and a long narrow beak as may be seen in Figure 8.

FIGURE 8. Showing a bird with a "crow head", a result of an inadequate protein intake.

The relationship between this crow head development was very definitely associated with inadequate protein intake, as will be seen in Table 6.

TABLE 6.—INFLUENCE OF PROTEIN ON HEAD DEVELOPMENT

Pen	Percent Crow Heads: Males	Percent Crow Heads: Females
	%	%
1	87	83
2	50	70
3	24	27
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0

Many poultrymen believe that a genetic factor is responsible for the production of this head type. These results would show that it is due to a dietary rather than a hereditary factor. It would seem probable that any ration which is deficient in any factor necessary for the proper nutrition of chicks would result in the production of "crow heads".

SUMMARY

1. The optimum protein content for growth in chicks during the first six weeks on the usual type of ration is approximately 25%, from six to ten weeks 18 to 20%, and after this time the protein requirement is about 15%.

2. The optimum amount of protein in a diet for growing chicks over a twelve week period is approximately 19%.

3. A level of protein over 25% is approaching an excess, detrimental to growth.

4. The efficiency of food utilization decreases with age, and mortality is lessened, other factors being equal, the nearer the protein content to optimum.

5. Both high and low protein intake, particularly the former, tend to destroy the barring and to change the contour and texture of feathers. The optimum protein level for growth is not necessarily the optimum level for correct feather development.

6. Slipped tendons are not due primarily to a high protein intake *per se*.

7. The development of "crow heads" is a dietary rather than a genetic factor.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the helpful suggestions and advice of Professor W. R. Graham throughout the course of this experiment.

Part of the cost of this experiment was defrayed by a grant from the Empire Marketing Board.

Since the conclusion of this experiment Gerricke and Platt (New Jersey Agric. Exp. Station, Bulletin No. 543, 1932), have found that feather development in Barred Rock chicks was improved proportionally with increased amounts of protein in the ration.

REFERENCES

1. Carrick, C. W., Hauge, S. M., and Prange, R. W. A milkless, greenless, gritless, all-mash ration for growing chicks. Poul. Sci. *6* : 162. 1927.
2. Carver, J. S., St. John, J. L., Aspinall, F. E., and Flor, I. H. Protein requirements of chickens. Poul. Sci. *11* : 45. 1932.
3. Heuser, G. F. and Norris, L. C. The influence of the protein level on the rate of growth in chickens. Report World's Poultry Congress, 328. 1930.
4. Holst, W. F. A consideration of the protein requirements of growing birds. Report World's Poultry Congress, 183. 1927.
5. Milne, H. L. Protein requirements of growing birds. Sci. Agric. *12* : 604. 1932.
6. Morris, L., Thompson, R. B., and Heller, V. G. The effect of varying the amounts of protein in the poultry ration on chick growth and subsequent egg production. Poul. Sci. *11* : 364. 1932.
7. Mussehl, F. E., and Gish, D. E. The protein requirements of growing chicks. Poul. Sci. *5* : 20. 1925.
8. Norris, L. C. and Hueser, G. F. The relation of the protein requirement of chicks to the rate of growth. Poul. Sci. *9* : 378. 1930.
9. St. John, J. L., Carver, J. S., Helphrey, J. P., Miller W. and Cassel, L. W. The effect on growth of various protein levels of dry skimmilk in a chick mash. Poul. Sci. *9* : 320. 1930.
10. Swift, R. W., Black, W., Voris, L., and Funk, E. M. The optimum protein content of rations for growing chicks. Poul Sci. *10* : 288. 1931.

Résumé

ÉTUDE SUR LA QUANTITÉ DE PROTÉINE NÉCESSAIRE AUX POUSSINS. J. D. McConachie, W. R. Graham, Jr., et H. D. Branion, Collège d'Agriculture de l'Ontario, Guelph, Ont.

La quantité optimum de protéine pour la croissance des poussins qui reçoivent une ration du type habituel est d'environ 25% pendant les six premières semaines; elle est de 18 à 20% de six à dix semaines, après quoi elle est d'environ 15%. Pour une période de douze semaines la quantité optimum de protéine que doit contenir le régime alimentaire des poussins est d'environ 19%. Un niveau de protéine dépassant 25% est excessif et peut nuire à la croissance. L'utilisation efficace de la nourriture décroît avec l'âge, et la mortalité est plus faible lorsque la proportion de protéine se rapproche de l'optimum, tous les autres facteurs étant égaux. Une absorption élevée et faible de protéine, spécialement la première, tend à détruire les barres et à changer le contour et la texture des plumes. Le niveau optimum de protéine pour la croissance n'est pas nécessairement le niveau optimum pour le bon développement des plumes. La haute absorption de protéine n'est pas la première cause du glissement des tendons. Le développement de "têtes de corneille" est un facteur diététique plutôt qu'un facteur génétique.

BACTERIOLOGICAL STUDIES OF DRESSED POULTRY

I. PRELIMINARY INVESTIGATIONS OF BACTERIAL ACTION AT CHILL TEMPERATURES[1]

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INTRODUCTION

In March, 1934, the need for bacteriological study of the changes occurring in chilled dressed poultry was suggested by Mr. W. A. Brown, Chief, Poultry Services, Dominion Live Stock Branch. While it was realized that microbial spoilage occurred at the temperatures commonly employed for storing the chilled product, it was felt that more definite information was required concerning the nature of the bacterial changes involved and the factors which determine the keeping quality of dressed poultry. Bacteriological studies were undertaken extending from March, 1934, to January, 1935, in the course of a co-operative investigation by the Department of Agriculture and the National Research Council in which chemical and physical aspects of the problem were also considered.

Investigational work on the microbiology of animal products in cold storage has been largely confined to the study of meat. While many of the findings are doubtless applicable to the question of refrigeration of poultry, yet differences in the physical nature of the products involve the consideration of special factors influencing keeping quality. In 1908 Stiles (*8*) reporting the examination of chickens kept in cold storage at a temperature from 2° to 8° F. found living organisms in the flesh after 610 days. In a study of market cold-storage chickens held at 13° F. Pennington (*5*) found appreciable numbers of organisms in the edible portions even after 4 years, though the numbers tended to decline with storage.

As the temperatures of storage employed by the above-mentioned workers are below those at which microbial growth may be said to occur, deterioration of poultry under such conditions results from physico-chemical and enzymatic changes rather than from microbiological action. The lowest temperature recorded for bacterial growth appears to be −7 5°C (18.5° F.) as reported by Bedford (*1*) in a study of marine organisms. At this temperature certain species of *Micrococcus* and *Achromobacter* were capable of slow development. In a study of the cold tolerant microflora of meat, Haines (*3*) found that with the mold *Sporotrichum carnis* growth did not cease until between −7° and −10° C. (14° to 19.4° F.). Below −10° C. (14° F.), according to the same author (*4*), no microbial growth of any kind occurs on frozen meat. Berry (*2*) places the critical temperature for microbial growth at 15° to 20° F.

At temperatures approximating 0° C. (32° F.), however, various species of bacteria, molds and yeasts are capable of development, as has been shown by numerous studies with organisms isolated from soil, fish, meat, vegetables and other sources. Consequently microbial development might be expected to be an important factor in determining the keeping quality

[1] Contribution No. 34 (Journal Series) from the Division of Bacteriology, Dominion Experimental Farm, Ottawa.
[2] Dominion Agricultural Bacteriologist and Graduate Assistant respectively.

of poultry stored at such temperatures commonly employed for the chilled, as distinct from the frozen, product. In a study of the effect of different holding temperatures upon various chemical and biological changes, Pennington, Hepburn, St. John and Witman (7) noted increases in bacteria in both muscles and skin of chickens held at 0° C. and 7.2 to 12 8° C. though the increases were much less marked than at ordinary room temperatures.

EXPERIMENTAL

Preliminary Tests

The poultry placed at our disposal was supplied by the Live Stock Branch, Dominion Department of Agriculture and the Poultry Division Experimental Farms. Considerable preliminary work was conducted on various lots of packed birds held at 30° and 32°F. with the object of testing various methods of analysis and the elaboration of a technique most suitable for the evaluation of changes occurring during storage.

Bacterial plates of the numbers of organisms on the skin surface and in the muscular tissue, using incubation temperatures of 37°, 28°, 20° and 2 2° C. showed that 37° did not permit of growth of the maximum numbers of organisms, while incubation at 2 2° or 20° gave no advantage over 28° C. Of the organisms which developed, both from the skin and muscle samples, a large proportion were ammonifying bacteria. *Bact. coli* was present in only very insignificant numbers, indicating no development of this type either on the surface or in the tissue. Growth of organisms on the skin was more definite than in the tissues. Counts from the thigh showed greater variations and were generally higher than from the breast muscle. Tests for anaerobes gave no more pronounced indication of growth than aerobic plates in the birds examined.

STUDY OF DRESSED POULTRY STORED AT 30° AND 32° F.

In this experiment 144 birds were examined, which had been prepared by the Poultry Division, Experimental Farm and the Poultry Services Division, Live Stock Branch. After killing and dressing, the birds were transported to the refrigeration plant of the National Research Council and pre-cooled to 30° F. over night. They were then packed in the regular manner, 8 birds to a box. Two boxes (16 birds) were examined when freshly packed and the remainder stored in equal lots at 30° F. and 32°F. respectively. At the end of 2, 4, 6 and 8 weeks two boxes (16 birds) were removed from each of the cold storage chambers for bacteriological examination. To facilitate handling the birds, the killing, packing, etc. were so arranged that the analytical work at every sampling was spread over four consecutive days.

Methods

Bacterial counts were made of the skin and the breast tissue of each bird. For the former, four portions of skin, 1 sq. cm. each, were cut with a scalpel from the breast, back, rump and thigh respectively and added to 100 cc. sterile 0 85% NaCl in a 200 cc. Erlenmeyer flask containing approximately 15 gm. broken glass. The flask was shaken for 5 minutes and further dilutions prepared as required. Duplicate plates were prepared from each dilution employed, using nutrient agar and incubating at 28 °C. for 4 days. Bacterial numbers were estimated per square centimeter skin surface.

For the examination of the breast tissue, the outer breast muscle from one side was first cut away and 4.0 gm. of the inner muscle tissue removed aseptically and weighed into a sterile 200 cc. Erlenmeyer flask containing 15 gm. broken glass. After the addition of 100 cc. sterile saline the flask was shaken for 10 minutes. Nutrient agar plates were prepared, incubated at 28° C. for 4 days and numbers of bacteria estimated per gram of tissue.

RESULTS AND DISCUSSIONS

The results from the bacteriological analyses of 144 birds are shown in Table 1 in which are summarized the logarithmic averages for the counts obtained from 16 birds in each temperature and storage period group. It will be noted from the table that during the period of storage there is a notable increase in the average bacterial numbers on the skin surface at both temperatures, the increase being more pronounced at 32° than at 30° F.

It was found that the birds acquired a surface odour before there was any apparent decomposition of, or significant increase of bacteria in, the muscle tissue examined. In addition to the pronounced increase of bacteria on the skin during storage it was observed that the odour from the plate cultures was very similar to that which eventually developed on the stored birds. It is therefore believed that the deterioration of dressed poultry at 30° and 32° F. to the point where the birds acquire a noticeable odour is essentially a surface spoilage due to bacterial growth. With the birds held at 32° F. this initial sign of spoilage was first observed after 4 weeks, being apparent with those stored at 30° F. at the following (6 wk.) sampling. From Figure 1, in which the logarithms of the average bacterial counts are plotted against time, it is noted that at approximately log. 6 4 (2,500,000 per sq. cm.) the stage is reached at which surface odour is first apparent. From the data there is indication that birds held at 30° F. remain approximately one week longer than at 32° F. before reaching the initial stage of spoilage, namely 5 weeks as compared with 4.

Compared with the bacterial counts of the skin, those obtained from the examination of the breast tissue were very low. The presence of small numbers in the first examination (1 day) confirms the observations of Pennington (6), who showed that the presence of a few bacteria twenty-four hours after death, even with careful and rapid chilling, could be demonstrated in breast and thigh muscle. During

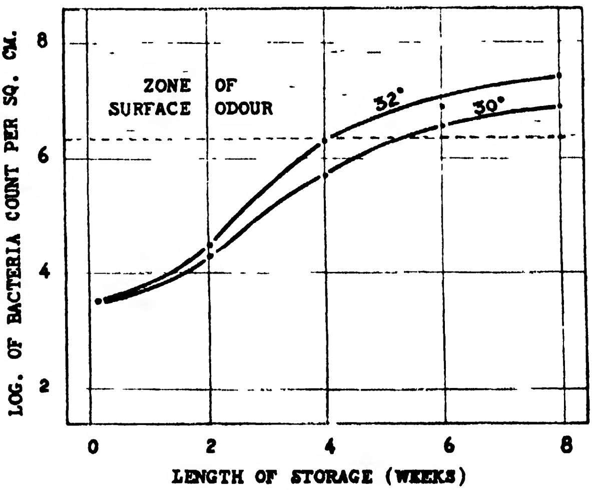

FIGURE 1. Relation of length of storage at 30° and 32° F. to development of bacteria on skin of dressed poultry.

TABLE 1.—SUMMARY OF BACTERIAL COUNTS FROM SKIN SURFACE AND INNER BREAST MUSCLE OF 144 BIRDS

Storage period	Stored at 30° F			Stored at 32° F.		
	No of birds	Bacterial counts (logarith. aver)		No of birds	Bacterial counts (logarith. aver.)	
		Skin (sq cm)	Muscle (gm)		Skin (sq. cm)	muscle (gm.)
1 day (precooled)	16	3,380	32	—	—	—
2 weeks	16	20,400	27	16	30,800	32
4 weeks	16	551,800	121	16	2,021,000	376
6 weeks	16	3,635,000	776	16	7,396,000	1,880
8 weeks	16	7,920,000	672	16	25 300,000	290

TABLE 2.—CHARACTERISTICS OF PREDOMINANT BACTERIAL TYPES ON SKIN OF DRESSED POULTRY STORED AT 30° AND 32° F.

Cult. No.	Form	Size (μ) N A. 20°	Motility	Spores	Gram stain	Gelatine liquef	NO_3 reduction	Acid (dextrose)	Gas (dextrose)	Indol	Action in milk	Optimum temp °C.	Growth at 37° C. (10 days)	Chromogenesis	Generic classification
1	coccus	0.7–1.1 diam.	—	—	—	—	+	—	—	—	—	20–28	—	—	Micrococcus
2	coccus	0.6–0.9 diam.	—	—	—	—	+	—	—	—	—	20–28	—	—	Micrococcus
3	rod	1.2–3.5 × 0.5–0.6	+	—	—	+	—	+	—	—	peptonized	20	sl	—	Achromobacter
4	rod	0.8–2.0 × 0.5–0.7	—	—	—	+	—	+	—	—	—	20	—	—	Achromobacter
5	rod	0.8–1.8 × 0.6	+	—	—	—	—	+	—	—	—	20–28	—	yellow	Flavobacterium
6	rod	0.8–2.0 × 0.5–0.7	—	—	—	—	—	+	—	—	—	20	—	—	Achromobacter

the period of our test, increases were relatively slight and irregular, the numbers of organisms being regarded as too low to indicate microbial decomposition. It was furthermore noted that no spoilage of tissue was present which could be determined organoleptically. On the other hand surface deterioration progressed until the conclusion of the tests. To the characteristic surface odour due to bacteria was added at later stages the distinctive musty odour arising from the development of molds, more particularly on the birds stored at 32° F.

STUDY OF BACTERIAL TYPES

In addition to the quantitative determinations reported above, a study was made of the bacterial types most prevalent on the skin of the birds. For this purpose the plate cultures made at the end of the period of storage were used, by which time any possible adjustment to a typical cold storage microflora would have taken place.

From the plate cultures from 8 different birds at 30° F. and at 32° F. isolations were made from the predominant types of colonies, at least four colonies from each plate. In this way some 70 cultures were obtained which, after morphological and physiological comparisons, were reduced to six types regarded as distinct species. The comparatively small number of types predominating confirmed the macroscopic observations of colony types on the plate cultures. A summary of the characteristics of the six predominant types is given in Table 2.

With respect to the types occurring at the different storage temperatures, no special distinction was possible between the birds stored at 30° and 32° F. This tends to confirm observations made throughout the experiments in which the plate cultures were similar in general colony appearance, odour, etc. The effect of the difference of temperature studied on the bacterial development was thus quantitative rather than qualitative. It is of interest to note that the predominant types were species which though capable of growth at temperatures near the freezing point, develop best at 20° to 28° C. Little or no growth occurred at 37° C., supporting earlier observations as to the unsuitability of this temperature for studying the microflora of chilled poultry.

SUMMARY

The deterioration of dressed poultry at 30° and 32° F. to the point where the birds acquire a noticeable odour is essentially a surface spoilage.

The first odour noticeable is due to the development of bacteria on the skin surface, and reaches an extent which may be objectionable before there is any significant decomposition of, or notable increase of bacteria in, the muscular tissue. The first signs of surface odour are apparent when the bacteria count on the skin has exceeded approximately 2,500,000 per square centimetre.

From the bacteriological point of view birds held at 30° F. remain approximately one week longer before reaching the initial stage of spoilage than those held at 32° F.

The predominant types of bacteria developing on the skin during storage were representative of the genera *Micrococcus*, *Flavobacterium* and *Achromobacter*, six species being described, all cold-tolerant rather than

cold-loving. Differences in bacterial development at 30° and 32° F. were quantitative rather than qualitative.

REFERENCES

1. Bedford, R. H. Marine bacteria of the Northern Pacific Ocean. The temperature range of growth. Contrib. to Can. Biol. and Fish. 7, No. 34 (Series C. No. 10) 1933.

2. Berry, J. A. Cold-tolerant micro-organisms and frozen pack. The Canner. Feb. 24, 1934.

3. Haines, R. B. The influence of temperature on the rate of growth of *Sporotrichum carnis*. J. Exp. Biol. *8* · 379. 1931.

4. ————. Report of the Food Invest. Board for 1931. Sect. A. Meat. p. 46-51. 1932.

5. Pennington, M. E. A preliminary study of the effects of cold storage on eggs, quail and chickens (H. W. Wiley). U.S. Dept. Agr. Bur. Chem. Bull. No. 115, Sec. 4, p. 57-99. 1908.

6. ————. Proc First Int. Cong. Refrig. Ind. *2* . 243. 1909.

7. ————, Hepburn, J. S., St John, E. Q. and Witmer, E. The influence of temperatures above freezing on the changes in chemical composition, bacterial content and histological structure of the flesh of the common fowl. Proc. Amer. Soc. Biol. Chem. 1916 J. Biol Chem. *29* xxxi-xxxii. 1917

8. Stiles, G. W. A preliminary study of the effects of cold storage on eggs, quail and chickens. (H. W. Wiley) U S. Dept Agr. Bur Chem. Bull. No. 115. Sec. 3, p. 44-57. 1908

Résumé

ÉTUDES BACTÉRIOLOGIQUES DES VOLAILLES HABILLÉES. A. G. Lochhead et G. B. Landerkin, Ferme expérimentale fédérale, Ottawa.

La détérioration à une température de 30° et 32° F. des volailles habillées jusqu'au point où l'odeur devient prononcée, est essentiellement une décomposition de surface. La première odeur constatée est due au développement de bactéries sur la surface de la peau; elle devient assez forte pour incommoder avant qu'il y ait une décomposition significative du tissu musculaire ou une augmentation notable de bactéries dans ce tissu. Les premiers signes d'odeur de surface sont apparents lorsque la numération des bactéries sur la peau dépasse environ 2,500,000 par centimètre carré. Au point de vue bactériologique, les sujets conservés à 30° F. mettent environ une semaine de plus à atteindre les premières phases de la décomposition que ceux qui sont conservés à 32° F. Les types prédominants de bactéries qui se développent sur la peau pendant l'entreposage représentaient les genres *Micrococcus, Flavobacterium* et *Achromobacter;* six espèces sont décrites, toutes tolérantes au froid plutôt que recherchant le froid. Les différences notées dans le développement des bactéries à 30° et 32° F. étaient des différences quantitatives plutôt que qualitatives.

THE EFFECT OF FEEDING DEAMINIZED VS. UNTREATED COD LIVER OILS UPON GROWTH, EGG PRODUCTION AND MORTALITY OF POULTRY[1]

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Cod liver oils of high free fatty acid content have been discriminated against for feeding purposes for some time past. Investigators have been unable to show, however, that free fatty acids similar or identical to those commonly found in cod liver oils are in any way deleterious when fed to poultry. Oils of high content have been shown to cause poor growth, lack of uniformity and high mortality in growing chicks, but this effect has not been shown to be caused by the fatty acids of the oil *per se*, since no attempt was made to show that this fraction was solely responsible. A review of the literature indicated that cod liver oils were not made up entirely of neutral glycerides but contained impurities mostly of a nitrogenous nature, originating from the livers from which the oil was rendered. Among these, certain amines (products of protein decomposition) were sometimes found which were decidedly toxic in their biological effect to mice and, when in pure form, to small birds. In view of these facts a series of cod liver oils was examined for content of this nitrogenous fraction and a cod liver oil of medium quality tested biologically upon poultry for possible toxic effect.

Nitrogen determinations upon a series of oils indicated the presence of such a fraction in even carefully refined oils for human consumption. Although not necessarily always the case, the analyses indicated that, usually, high free fatty acidity and high nitrogen content were to be found in the same oils. Oils which were prepared by the sun rendering process were higher in the nitrogenous fraction than those steam rendered. A very representative composite sample of pilchard oil (a body oil) was remarkably low in this fraction. A cod liver oil known to have been made from stale livers was high in free fatty acids and nitrogen even though steam rendered. It appeared therefore, that oils originating from stale livers and/or improperly processed were apt to be high in both fractions.

A representative sample of a sun rendered cod liver oil containing 29.6% of free fatty acids (expressed as oleic) and 0.31% of nitrogen was used for experimental purposes. This oil was medium dark in colour and not particularly strong or fishy in odour. In these respects it might be said to be a sun rendered oil of better than average quality. By the use of a suitable technique, the nitrogenous fraction was removed from this oil without interfering with its vitamin potency as indicated by biological tests. This oil, thus deaminized, was fed to large groups of chicks through the growing, rearing and first year egg production periods as 1% of a ration previously proven to be satisfactory for the purpose required (growth and egg production). This treatment was controlled by feeding the same oil in its original condition without deaminization or treatment of any kind to comparable birds.

The following results were obtained. The feeding of the oil containing the nitrogenous impurities reduced the growth of the chicks during the brooding and rearing periods. The effect was much more marked with the cockerels than the pullets. It also greatly increased the variability of the chicks to which it was fed. The removal of this nitrogenous fraction also permitted the pullets receiving the oil, thus treated, to make more efficient use of their feed for purposes of egg production. Mortality was slightly in favour of the individuals receiving the deaminized oil in every case.

[1] Author's abstract of a material which will appear shortly as a technical bulletin of the Dominion Department of Agriculture, Ottawa.
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It is concluded that oils containing appreciable quantities of nitrogenous products should not be used for feeding purposes. Since in most cases these oils will also be high in free fatty acids, oils of high free fatty acid content should be discriminated against. Sun rendered oils, or oils not so rendered, but arising from stale livers, will usually be high in both free fatty acid and nitrogen content and should not be used for feeding purposes. It would appear from the results of this investigation that oils of high free fatty acid content shown previously by other investigators to cause poor growth with marked lack of uniformity and very high mortality were probably also high in this nitrogenous fraction and that this fraction was responsible for the results obtained. Since the oils which they used were purchased upon the open market (1930), the availability of such oils is evident. It may be appreciated that very serious consequences may follow their use.

Résumé

L'EFFET DE L'EMPLOI D'HUILE DE FOIE DE MORUE PRIVÉE ET NON PRIVÉE DE SES VITAMINES SUR LA CROISSANCE, LA PONTE ET LA MORTALITÉ DES VOLAILLES. H. S. Gutteridge, ferme expérimentale centrale, Ottawa.

L'auteur conclut que les huiles qui renferment une quantité appréciable de produits azotés ne devraient pas être employés pour l'alimentation. Comme la plupart des huiles de ce genre ont une forte teneur en acides graisseux libres, la présence d'une grosse quantité d'acides graisseux libres indique que ces huiles ne devraient pas être employées. Les huiles extraites au soleil ou les huiles non extraites de cette façon mais provenant de foies rances sont généralement riches en acides graisseux libres et en azote et ne devraient pas être employées pour l'alimentation. Il semble d'après les résultats de cette enquête, que les huiles qui contiennent une forte proportion d'acides graisseux libres et qui ont été la cause d'une pauvre croissance, d'un manque prononcé d'uniformité et d'une mortalité très élevée dans les expériences faites par d'autres investigateurs, contenaient aussi probablement une forte proportion de cette fraction azotée et c'est cette fraction qui a été la cause des résultats obtenus. Comme les huiles dont ils se sont servis avaient été achetées sur le marché public (1930), on voit que l'emploi de ces huiles peut être suivi de conséquences très sérieuses.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index number of wholesale prices in Canada was slightly lower in May. Lower prices for wheat and silver were the chief factors in the recession. The index of prices of vegetable products fell from 69 4 in April to 68 0 in May. Prices of non-metallic minerals and of chemicals and allied products were also lower. The most substantial advance was registered in the non-ferrous metals group. This index rose from 67 9 to 70 7. On the whole, however, prices were lower and the index of wholesale prices declined to 72.3.

Retail prices.—The index of retain prices and costs of services was unchanged in May. Prices of foods were slightly higher and the rental index computed only in October and May was again higher. Fuel prices showed not only a season of decline but prices were below those of a year ago. Retail prices in May, 1935, were in general only a little higher than in May, 1934.

Physical Volume of Business.—The physical volume of business reached a new high point in the period of recovery, being 103 2 compared with 100 in 1926 and 98 3 in April of this year. The index of industrial production advanced from 97 7 to 104.4. Mineral production was lower than in April although exports of nickel, shipments of silver, imports of bauxite and coal production showed substantial gains. The index of manufacturing advanced from 94 0 to 105 1. Practically all the industries included in this group showed increased activity but iron and steel production was slightly lower than in the previous month and automobile production dropped from 102 9 to 87. The index of construction was 38 1 compared with 37 1. The number of contracts awarded was higher but building permits were lower and the cost of construction remained stationary. Car loadings were somewhat lower. Exports and imports were both higher. The agricultural factors will be discussed in detail in another section. It may, however, be pointed out that agricultural marketings and cold storage holdings were lower in May than in April.

Agricultural Products.—The index number of wholesale prices of Canadian farm products receded to 64 1 in May. There was a very pronounced advance in the prices of animal products, the index rising from 72 9 in April to 74 4 in May. Prices of hogs and lambs advanced sharply because of comparatively light shipments. Prices of good to choice steers were higher both at Toronto and Winnipeg during the first half of the month but declined later on because of weaker prices in United States. Prices of calves were lower in both Toronto and Winnipeg. The index of prices of field products declined from 59 8 in April to 58 0 in May. The average price of No. 1 Manitoba northern wheat was nearly two cents below that during April, while prices of oats dropped a little less. The average price of No. 2 C. W. barley declined from 45 9 to 42.3 Cents. No. 1 C. W. Flax dropped from 140.9 to 134.0. The wheat crop in Western Canada is more satisfactory than a year ago. Southern Saskatchewan is reported to have a very fair prospect and while it has been very dry in sections of both Alberta and Saskatchewan, there is prospect of at least an increase in supplies of feed. In sections, however, the crop is late and favourable harvest weather will be necessary. Stem rust is reported to be prevalent.

The index of grain marketings declined from 91 8 in April to 86 3 in May. There was a smaller movement in wheat, oats, barley, rye and flax. The index of shipments of wheat fell more than seven points, that for oats nearly nine points, and the index for barley marketings was about three points less than that registered in April.

Total live stock marketings were only slightly lower than in April and the index receded less than two points. The most marked decline was in the movement of sheep and lambs. This index is based on deliveries at public markets.

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION
COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1934	71.6	59.0	53.9	67.6	78.9	94.2	93.6	88.5	114.2
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.8
Nov.	71.2	61.2	55.7	70.4	79.4	96.5	97.0	51.2	130.4
Dec.	71.2	61.6	56.0	70.9	79.0	92.4	91.0	36.0	135.7
1935									
Jan.	71.5	61.4	55.7	71.0	78.9	97.5	97.8	30.6	143.7
Feb.	71.9	62.0	55.7	72.6	79.1	100.6	101.1	62.2	141.2
Mar.	72.0	62.7	56.4	73.3	79.0	94.2	93.3	65.4	143.2
Apr.	72.5	64.7	59.8	72.9	78.8	98.3	97.7	91.8	135.8
May	72.3	64.1	58.0	74.4	78.8	103.2	104.4	86.3	123.2

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1933, p 15
2. Wholesale prices of Canadian products of farm origin only See Prices and Price Indexes 1913-1933, p. 33, and Monthly Mimeographs 1934 and 1935.
3. Wholesale prices of grains, fruits and vegetables
4. Wholesale prices of Animals and Animal Products.
5. Including foods, rents, fuel, clothing and sundries. See Prices and price Indexes 1913-1928, pp. 181-185, 290-293 1926 = 100
Prices and Price Indexes 1913-1931, p. 108, and Monthly Mimeographs 1934-1935.
6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

General Situation.—The economic situation in general during the first five months of 1935 has been characterized by comparative stability of wholesale prices as a whole. Prices of Canadian farm products have tended toward higher levels except during the month of May. Prices of field products have shown the most marked decline. Although the index of prices of animal products has varied more

from month to month, the trend has been definitely upward. Retail prices have largely reflected the condition of the wholesale market, such variations as have taken place have been relatively small. The physical volume of business has varied as much as nine points, the peaks being reached in February and May. Probably the weakest points in the whole economic position of the country at the present time are the continued slackness in construction industries and the comparatively light movement of wheat into export markets. In regard to the latter it is now evident that the carryover at the end of July will be much larger than was anticipated earlier in the crop year. Exports in general have been much higher than in the corresponding months of 1934.

Compared with a year ago the index of wholesale prices is about one point higher. There has, however, been more substantial improvement in prices of Canadian farm products. The total index in May 1935, was about five points above that for May, 1934. In spite of the decline in May of this year the index of prices of field products was still nearly 7 points higher than a year ago and in the case of animal products the gain has been about 9 points. The physical volume of production and industrial production are both well above the position reached in May, 1934 Collections appear to be better and optimism more general. Progress toward recovery has been substantial even though not as rapid as could be wished for or as general as desired.

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE, OTTAWA, PRINCIPALEMENT AVEC LES DONNÉES COMPILÉES AU BUREAU FÉDÉRAL DE LA STATISTIQUE

Le chiffre indice des prix du gros au Canada a subi un léger recul en mai, principalement à cause de la baisse de prix enregistrée sur le blé et sur l'argent. L'indice des produits végétaux, qui était à 69·4 en avril est tombé à 68·0 en mai. Il y a eu régression également chez les minéraux non métalliques et les produits chimiques. C'est le groupe de métaux non ferreux qui a enregistré la plus forte hausse, de 67·9 à 70·7. Dans l'ensemble cependant, les prix étaient plus bas et l'indice des prix du gros est tombé à 72·3.

Prix du détail.—L'indice des prix du détail et des frais de services est resté stationnaire en mai. Les prix des aliments ont un peu remonté, de même que l'indice des loyers, qui n'est computé qu'en octobre et mai. Les prix du combustible, qui sont allés en diminuant toute la saison, étaient inférieurs à ceux de l'année dernière. En général, les prix du détail en mai 1935 n'étaient qu'un peu plus élevés qu'en mai 1934.

Volume physique des affaires.—Le volume physique des affaires a atteint un nouveau point élevé dans la période de redressement; il était à 103·2 contre 100 en 1926 et 98·3 en avril de cette année. L'indice de la production industrielle est monté de 97·7 à 104·4. La production minérale était inférieure à celle d'avril, malgré l'augmentation sensible enregistrée dans les exportations de nickel et d'argent, les importations de bauxite et la production du charbon. L'indice des produits manufacturés s'est élevé de 94·0 à 105·1. Presque toutes les industries comprises dans ce groupe ont fait preuve d'une activité croissante, mais la production du fer et de l'acier était un peu moins forte que dans le mois précédent et la production des automobiles est tombée de 102·9 à 87. L'indice du bâtiment était de 38·1 contre 37·1. Le nombre de contrats passés était plus élevé mais les permis de construction avaient une moindre valeur et le coût de la construction est resté stationnaire. Les chargements de wagons étaient un peu moins nombreux, mais les exportations et les importations ont remonté. Les facteurs agricoles sont discutés en détail dans un autre paragraphe. Notons cependant que les ventes agricoles et les stocks entreposés au froid étaient moins élevés en mai qu'en avril.

Produits agricoles.—Le chiffre indice des prix du gros des produits de ferme canadiens est tombé à 64·1 en mai. Il y a eu une hausse très prononcée dans les prix des produits animaux, l'indice s'est élevé de 72·9 en avril à 74·4 en mai. Les prix des porcs et des agneaux ont beaucoup remonté à cause des expéditions relativement faibles. Les prix des bœufs, bons à de choix, ont remonté pendant la première moitié du mois à Toronto et à Winnipeg, mais ils sont retombés plus tard à cause de la faiblesse des prix aux Etats-Unis. Les prix des veaux ont diminué à Toronto et à Winnipeg. L'indice des prix des produits des champs, qui était à 59·8 en avril, est tombé à 58·0 en mai. Le prix moyen du blé du Nord Manitoba N° 1 est à peu près de deux cents inférieur à celui d'avril, et le prix de l'avoine a baissé également, mais un peu moins. Le prix moyen de l'orge C.O. N° 2 est tombé de 45 9 à 42·3 cents. Le lin C.O. N° 1 est tombé de 140·9 à 134·0. La récolte de blé de l'Ouest du Canada est plus abondante que celle de l'année dernière. On dit que les prévisions sont très bonnes dans le Sud de la Saskatchewan et que l'on prévoit une augmentation dans la récolte de fourrages en dépit de la sécheresse excessive qui a sévi dans certains secteurs de l'Alberta et de la Saskatchewan. Il y a cependant des districts où la récolte est en retard et où la température jouera un grand rôle dans le succès de la moisson.

L'indice des ventes de grain, qui était à 91·8 en avril est tombé à 86·3 en mai. Les expéditions de blé, d'avoine, d'orge, de seigle et de lin ont diminué. L'indice des expéditions de blé est tombé de plus de sept points, celui de l'avoine de près de neuf points, et celui des ventes d'orge d'environ trois points par rapport à avril.

Les ventes totales de bestiaux n'ont été que légèrement inférieures à celles d'avril et la baisse de l'indice n'a pas atteint deux points. La diminution la plus forte a été dans l'expédition de moutons et d'agneaux. Cet indice est basé sur les livraisons aux marchés publics.

Situation générale.—En général la situation économique pendant les cinq premiers mois de 1935 s'est caractérisée par une stabilité relative des prix du gros. Les prix des produits de ferme canadiens avaient aussi une tendance à la hausse, sauf pendant le mois de mai. Ce sont les prix des produits des champs qui ont le plus baissé. L'indice des prix des produits animaux a varié d'un mois à l'autre, mais la tendance était nettement à la hausse. Les prix du détail réfléchissaient principalement l'état du marché de gros, et les variations qui se sont produites ont été relativement faibles. Le volume physique des affaires a varié d'au moins neuf points, le maximum étant atteint en février et mai. Les points les plus faibles peut-être de la situation économique du pays à l'heure actuelle sont l'inertie continuelle de l'industrie du bâtiment et les expéditions relativement légères de blé sur les marchés d'exportation. En ce qui concerne ce produit, il est maintenant évident que le reliquat à la fin de juillet sera beaucoup plus fort que l'on ne prévoyait au commencement de l'année de récolte. Les exportations en général ont été plus fortes que dans les mois correspondants de 1934.

L'indice des prix du gros est d'environ un point plus élevé que l'année dernière, mais l'amélioration constatée dans les prix des produits de ferme canadiens a été considérable. L'indice total en mai 1935 était d'environ cinq points au-dessus de celui de mai 1934. Malgré la baisse notée en mai de cette année, l'indice des prix des produits des champs était encore à peu près de 7 points plus élevé que l'année dernière, et l'augmentation était de près de 9 points pour les produits animaux. Le volume physique de la production et la production industrielle sont tous deux bien au-dessus du point qu'ils occupaient en mai 1934. Il semble que les recouvrements se font mieux et l'optimisme est plus général. Il s'est fait évidemment de grands progrès dans la voie du redressement quoique ces progrès n'aient pas été aussi rapides ni aussi étendus qu'on aurait pu le désirer.

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A BOTANICAL STUDY OF PASTURE MIXTURES[1]

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INTRODUCTION

In 1931 a number of pasture mixtures, including biennial and perennial species, were seeded on the Animal Husbandry Farm at the University of Alberta, chiefly with a view to supplying good pasturage for cattle and horses for several years. The mixtures were determined more or less empirically, since little exact knowledge was available regarding the behavior of specific grasses and legumes in association with one another, when grown under Edmonton climatic and soil conditions. Considerable variety was introduced into the mixtures with a view to providing an opportunity for some rather careful studies over a number of years regarding the changes in vegetative composition, relative survival of different species, relative yield of pasturage for different species in mixtures, and possibly other important features, which might lead to conclusions valuable for future use in compounding pasture mixtures for conditions similar to those of the Edmonton district. It was decided to confine attention to six of the mixtures, these appearing to offer best opportunities for studies likely to lead to significant results.

The Department of Animal Husbandry of the University very kindly made possible the observations herein reported, supplied information regarding the field and pasture management of the different pastures, provided materials for the building of enclosures and rendered other encouraging assistance, for all of which the authors wish to express their appreciation.

FIELD AND PASTURE MANAGEMENT

The land on which the pasture mixtures were seeded had previously produced crops as follows:

Pasture A, oats and several crops of sunflowers since breaking in 1922;

Pasture B, rape as well as grains in former years;

Pasture C, grain mixtures, alfalfa, rape and sunflowers in different years;

Pasture D, turnips in 1926, oats from 1926 to 1930;

Pastures E and F, grain mixtures, alfalfa, rape and sunflowers for hog runs in different years up to 1930.

In 1930 all these areas were plowed and thoroughly fallowed to destroy weeds. In the early summer of 1931 the land was cultivated, harrowed and packed in the preparation of a good seed-bed.

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Pasture Mixtures

Table 1 indicates the constituents of each pasture mixture, the amounts of seed used per acre, the dates of seeding and the acreage of each pasture.

TABLE 1.—KINDS AND AMOUNTS OF SEEDS USED IN THE PASTURE MIXTURE

Species	Pastures and pounds of seed used per acre					
	A	B	C	D	E	F
Brome grass	2 8		5 0	2.7		7.0
Crested wheat grass	2 5			2.0	5.0	
Slender wheat grass	0.7	5.0				
Kentucky blue grass	3.0		4.0	4.0	4.0	
Timothy		3.0				
Alfalfa	3 0		5.0		3.0	6.0
Altaswede red clover		4.0				
Alsike clover	2.0	3.0				
White Dutch clover			3.0	5.0	2 0	
Sweet clover	3 0			3 0		
Date of seeding in 1931	June 25 and 26	June 29	July 7	July 8	June 27	June 27
Number of acres	2 8	2 4	1 5	3 0	6 25	6.25

Description of Seeds

The kinds and quality grades of the seeds sown were as follows:

Sweet clover (*Melilotus alba.* Desr.): White blossom, Grade No. 1.

Alfalfa (*Medicago sativa* L.): Grimm, Grade No. 1.

Altaswede red clover (*Trifolium pratense* L.): Certified, Grade No. 1.

Alsike clover (*Trifolium hybridum* L.): Certified, Grade No. 1.

White Dutch clover (*Trifolium repens* L. var. *sylvestre,* race, *hollandicum*): Certified, Grade No. 1.

Brome grass (*Bromus inermis* Leyss.): Certified couch-free, Grade No.1

Kentucky blue grass (*Poa pratensis* L.): Grade No. 1.

Timothy (Phleum pratense L.): Grade No. 1.

Slender wheat grass (*Agropyron tenerum* Vasey): Certified couch-free, Grade No. 1.

Crested wheat grass (*Agropyron cristatum* Gaertn.) (unimproved strain) Certified couch-free, Grade No. 1.

The seeds were purchased in Edmonton, Alberta, from reputable seed firms.

Method of Seeding

The small seeds (sweet clover, alsike clover, Altasweede red clover, white Dutch clover, alfalfa, Kentucky blue grass and timothy) were mixed and then seeded through a grass seeder attachment on the front of a disc grain drill, the seeds falling into the shallow furrows made by the discs. The larger seeds were sown broadcast by hand and covered by harrowing. All the pastures except one were seeded in one direction only. Pasture B, however, was seeded in two directions at right angles to each other.

Post-seeding Management

Pasturing management for all six pastures was under the direction of the Department of Animal Husbandry. No formal nor inflexible system was practised. Weedy patches in some pastures were mowed at intervals the first season to prevent re-seeding of the weeds and smothering of the crop seedlings. All pastures, except D, were grazed by cattle the first fall because of the excessive growth during an unusually moist season. In 1932 grazing was commenced the last week in May on all the pastures and continued throughout the season, except pastures C and D, which were cut for hay the second week in July, and thereafter pastured until fall; and pasture A, which was rested for two weeks in July. Pastures C and D after cutting were grazed by cattle and by sheep respectively. Pasture A, after the July rest period, was cut for hay and then pastured by cattle. In 1933 all the pastures were grazed continuously from the last week in May until fall, pastures A, B, C and E by cattle, and D by brood mares and colts. Similarly in 1934 all the pastures were grazed continuously by cattle from about the middle of May until fall. No other treatments were given these pastures, except in the case of pastures B and D, which were top-dressed with barnyard manure in the summer of 1934.

METHODS

Methods were devised for studying the pastures with respect to changes in botanical composition, the relative survival of species in particular combinations, the extent of winter killing, the productivity of different mixtures and species, and the suppressive action of the various pastures on weeds.

In order to follow the changes in the botanical composition of the pasture sward, counts were made of plants of each species found in 12 systematically distributed strip-areas six feet long by two inches wide marked off in each pasture (Figure 1). Four similar strips were also marked off within each of three seventeen-feet square fenced enclosures (Figure 2) located in each pasture, to serve as checks on those in the grazed areas. To delimit the strip-area to be analysed a strong cord was stretched along both sides of it and drawn taut around the stakes shown in Figure 1. Plants occurring half or more on the inner sides of the cord were included in the count. The unit of vegetation on which the counts were based was a distinct plant possessing an independent root system, as nearly as this could be determined without actually lifting the plant. Difficulty was encountered in the second, third and fourth years in distinguishing individual plants from new tillers in the case of the turf-forming species. In some cases, for this reason, it was found necessary to make an approximate rather than an accurate count of the number of plants present. The results indicate that this method of procedure was sound.

Counts were made the first fall on all the pastures except B, where the plants were too severely trampled by livestock and too dry for positive identification. Three such counts were made in 1932—spring, summer, and fall. In 1933 due to uncontrollable circumstances two counts only were made, one in the spring and one in the fall. Two counts were also made at about the same times in 1934. It was hoped originally that the counts could be made at approximately the same dates each year, but this proved impossible owing to inclement weather and pressure of other work.

It was the intention to analyze the check strip-areas in the enclosures without disturbing the growth on them, but this was found to be impracticable after the first count in the spring due to the rankness of the growth. Consequently, it was found necessary to cut these areas prior to the time of counting. This was usually done when the yield cuts were made. The method of botanical analysis used was a modification of similar methods employed by Davies (*2*) at Aberystwyth, and Hein and Vinall (*7*) in Maryland.

The data were treated statistically and compiled into suitable tables indicating the botanical changes in the vegetation. The variability in the counts due to errors in sampling was measured by computing the standard error of the mean, using Hayes' "Deviation of the Mean Method" (*6*) and Camp's (*1*) formula: Standard Error of the Mean equals $\sqrt{\frac{\Sigma(X-\bar{X})^2}{n(N-1)}}$.

To determine the productivity of the pastures under investigation small areas six feet square within the enclosures (Figure 2) were cut at intervals during the seasons. Two such cuttings were made in 1932 and three in 1933 and in 1934. The dates of cutting were somewhat irregular due to weather conditions and other circumstances. The yield per acre of air-dried herbage for each pasture was computed on the basis of the weight of the green material cut from the six-feet-square areas and a two-pound composite sample made by combining equal random samples taken from the three lots of green herbage. The composite samples were air-dried at room temperature in the laboratory to approximately constant weights.

No attempt was made to compute standard errors for the yield results, as replication of the enclosures was considered insufficient to justify such treatment.

The percentages of leguminous and gramineous herbage present in the stands were determined by taking a one-pound composite sample from the herbage cut from each six-feet-square area. Small air-tight metal cans were used to transport the samples to the laboratory for analysis. The two kinds of herbage and the weeds were separated and weighed while still green, and their percentages of the whole determined. No attempt was made to separate and weigh the amount of each species present on account of the difficulty of identifying small bits of vegetation and the tremendous amount of work involved. The percentages of the more abundant species were merely estimated. This was done by spreading out each sample thinly on a long table, making a rough separation of the various species and estimating the percentage of each species by visual impressions. It was hoped by this method to obtain some idea of the relative productivity of the more important species in the mixtures. This method was employed successfully by certain European workers, notably Davies (*2*).

Seasonal growth of plants was studied by means of height measurements in the spring, again before the livestock were "turned in" in May, and just previous to each cutting in the enclosures. It was thought that data procured in this way would show differences in earliness and rapidity of growth of the different species.

Notes were also taken, both in the spring and in the fall, on such items as general appearance and density of the pasture sward; palatability, as indicated by evenness and closeness of grazing; the prevalence or absence

of bare and trampled-out areas; the presence or absence of weeds; regenerative power, rapidity and earliness of growth; and apparent drought resistance and winterhardiness of the constituent species. These notes were supplemented by photographs taken to show the unevenness of grazing and vigor of growth of plants.

REVIEW OF METEOROLOGICAL DATA

Precipitation

A general impression of the precipitation month by month for the period of observations may be had from the data in Table 2. These data were collected by the Department of Field Crops of the University on the Field Crops Farm, situated about two miles from the location of the pasture plots.

TABLE 2.—PRECIPITATION IN INCHES AT EDMONTON* DURING 1931–1934

Year	Jan †	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Totals
1931	0	0	1.25	0.44	1.93	6.60	3.53	4.47	0.70	0.97	0.75	0.95	21.59
1932	0.55	0.82	0.83	2.53	1.59	2.27	2.24	0.58	0.89	0.32	1.57	0.63	14.82
1933	0.45	0.74	1.93	0.66	2.05	3.32	3.03	1.30	2.07	1.69	0.98	2.85	21.07
1934	0.76	0.55	1.06	1.55	2.56	3.04	2.67	1.74	‡				

*Measurements of precipitation were made on the Field Crops Farm, two miles from the location of the pasture plots

†The snowfall data for the winter months were converted into rainfall data by dividing the former by 10.

‡Observations were concluded at the end of September, 1934

Temperature

The temperature conditions during the four years of the investigation were not unusually extreme, except in January, February, March and December of 1932 and 1933. The lowest Fahrenheit temperatures (atmosphere above the snow cover) reached during these months were, in 1932, −47°, −42°, −34° and −19°; in 1933, −19°, −30°, −23° and −40°; and in 1934, −26°, −23° and −5°, for January, February and March respectively. The temperature data presented in Table 3 were also obtained from the records of the Department of Field Crops of the University.

Weather conditions were particularly favorable from the time of seeding to the end of the first summer, and also the following spring and early summer, but thereafter rainfall was exceptionally deficient. The drought period occurring each year, except 1931, in the latter part of the summer, interfered considerably with the normal seasonal growth.

EXPERIMENTAL RESULTS

Changes in Botanical Composition

The data obtained by frequency counts of plants of various species have been averaged and the respective standard errors computed. The percentage frequency of each species has also been calculated. The results are given in Tables 4 to 9. Table 9 contains data obtained from studies of Pasture F for the fall of 1931 and the spring of 1932 only, as no further counts were made on this pasture because a part of it was destroyed by discing for the purpose of eradicating stinkweed and Canada thistle.

TABLE 3.—MINIMUM MONTHLY AND AVERAGE MONTHLY ATMOSPHERIC TEMPERATURES (FAHRENHEIT) AT EDMONTON DURING 1931, 1932, 1933 AND 1934

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1931												
Minimum	−9	+6	−30	+16	+27	+30	+40	+40	+28	+18	−18	−19
Date of occurrence	13	8	11	20	19	4	2	9	17	27	15	9
Average daily maximum temperature	31 2	40 2	28 6	56 1	63 7	68 1	72 8	70 8	60.0	54 6	32.0	23.8
Average daily minimum temperature	9 2	19 7	9 4	30 2	38 1	46 4	48 9	47 9	37 6	27 2	9.7	5.9
1932												
Minimum	−47	−42	−34	+24	+31	+34	+40	+29	+33	+5	−14	−23
Date of occurrence	31	1	7	2	15, 25	17	12	31	13, 22	28	14	8
Average daily maximum temperature	15 7	20 3	22 7	50 9	65 2	71 4	71 8	75 8	66 5	44.7	28 7	21.4
Average daily minimum temperature	4 2	6 4	1 2	33 3	40 9	48 2	49 4	49 2	39 9	24 9	11.0	4.1
1933												
Minimum	−19	−30	−23	+14	+31	+32	+39	+35	+26	+5	+3	−40
Date of occurrence	4	11	2	8	10	22	20	25	27	22	4	27
Average daily maximum temperature	14 1	17 6	29.6	47 2	62 1	69 5	72.7	75 5	59.1	45 7	38.3	−3.9
Average daily minimum temperature	5 0	4 7	6 4	27 6	39.1	45 0	47.7	47 8	37.4	23 8	23 0	−16.4
1934												
Minimum	−26	−23	−5	+19	+28	+33	+37	+25	*			
Date of occurrence	24	24	9	15	12	2	5	24				
Average daily maximum temperature	28 4	32 5	35 8	57 1	67 6	66 6	72 4	71 1				
Average daily minimum temperature	4 8	10 1	16 2	33 3	40 7	44 6	46.6	44 4				

*The investigation was concluded at the end of September, 1934.

TABLE 4.—FREQUENCY AVERAGES OF PLANTS OF SPECIES PER SQUARE FOOT AND PERCENTAGES AS DETERMINED BY COUNTS OF THE NUMBER OF PLANTS IN 12 SYSTEMATICALLY DISTRIBUTED SAMPLE STRIPS

Pasture A

Year	Season of counting		Brome grass	Crested wheat grass	Slender wheat grass	Kentucky blue grass	Alfalfa	Sweet clover	Alsike clover	Total	Annual weeds	Perennial weeds
1931	Autumn	F*	5.2±1.0	4.6±0.7	3.8±0.9	4.7±0.7	10.4±0.9	5.8±0.4	6.3±0.8	40.8	0.6	—
		%	12.7	11.3	9.2	11.5	25.5	14.2	15.4	100		
1932	Spring	F	9.0±1.1	6.0±1.4	6.8±0.8	8.9±1.5	6.9±0.7	6.0±0.6	2.4±0.4	46.0	—	0.1
		%	19.9	13.0	14.7	19.3	15.0	13.0	5.2	100		
	Summer	F	9.3±1.5	4.3±0.7	5.9±1.0	9.7±1.1	9.0±0.8	5.3±0.8	10.3±1.2	53.8	0.8	0.2
		%	17.2	7.9	11.0	18.0	16.8	9.9	19.1	100		
	Autumn	F	7.9±1.0	2.0±0.3	3.9±0.5	13.0±1.4	8.3±0.8	3.3±0.5	6.6±0.8	45.0	—	0.3
		%	17.6	4.4	8.7	28.9	18.4	7.3	14.7	100		
	Check Autumn (unpastured)	F	14.8±0.7	3.7±0.6	3.8±0.7	11.3±1.5	8.7±0.8	1.0±0.5	7.7±1.2	51.0	0.1	0.4
		%	29.0	7.3	7.5	22.2	17.1	2.0	15.1	100		
1933	Spring	F	9.1±1.2	2.2±0.5	1.9±0.1	12.3±1.7	6.0±0.4	—	3.9±0.8	35.4	—	—
		%	25.7	6.2	5.4	34.7	17.0	—	11.1	100		
	Check Spring (unpastured)	F	13.8±1.1	2.5±0.4	2.9±0.5	11.9±0.7	7.0±0.5	—	2.6±0.7	40.7	—	0.3
		%	33.9	6.1	7.2	29.3	17.2	—	6.3	100		
	Autumn	F	8.9±0.9	1.0±0.2	1.6±0.4	15.9±1.3	6.6±0.7	†0.2±0.1	5.0±1.3	39.2	0.1	0.2
		%	22.7	2.6	4.1	40.6	16.8	0.5	12.8	100		
	Check Autumn (unpastured)	F	12.7±0.9	1.7±0.3	1.5±0.3	13.9±0.9	7.8±0.5	—	3.6±1.0	41.2	0.1	0.5
		%	30.9	4.1	3.7	33.8	18.9	—	8.7	100		

TABLE 4.—FREQUENCY AVERAGES OF PLANTS OF SPECIES PER SQUARE FOOT AND PERCENTAGES AS DETERMINED BY COUNTS OF THE NUMBERS OF PLANTS IN 12 SYSTEMATICALLY DISTRIBUTED SAMPLE STRIPS—*Concluded*

Pasture A

Year	Season of counting		Brome grass	Crested wheat grass	Slender wheat grass	Kentucky blue grass	Alfalfa	Sweet clover	Alsike clover	Total	Annual weeds	Peren-nial weeds
1934	Spring	F	10 8±1.6	1 6±0 5	2 0±0 4	25.8±0.9	5.9±0 8	†0 5±0.2	4.5±1.6	51.1	0.1	0.1
		%	21.1	3 1	3.9	50 5	11.5	1.0	8.8	100		
	Check Spring (unpastured)	F	12 4±1 0	0.9±0 4	1.2±0.4	21 9±1 1	7 1±0 5	†0.2±0.1	3.4±1.1	47.1	—	0.2
		%	26 3	1 9	2.5	46 5	15.0	0 4	7.2	100		
	Autumn	F	7 1±0.1	0 3±0.2	1.2±0 3	28 0±1.1	6 4±0 7	—	—	43 0	—	0.1
		%	16 5	0 7	2 8	65.1	14.9	—	—	100		
	Check Autumn (unpastured)	F	10.5±0 9	—	0 7±0 3	24 4±0 9	6 3±0 4	—	2 6±0 2	44.5	—	0.2
		%	23 6	—	1 6	54 8	14.2	—	5 8	100		

NOTE—Standard errors of the means are given.
*F = frequency averages.
†Seedlings.
Dates of counts: 1931—November 3 and 4.
1932—April 30, June 6 and 7, August 20.
1933—May 13 (pasture), 24 (unpastured check), August 26 (pasture and unpastured check).
1934—May 19, September 14.

TABLE 5.—FREQUENCY AVERAGES OF PLANTS OF VARIOUS SPECIES PER SQUARE FOOT AND PERCENTAGES AS DETERMINED BY COUNTS OF THE NUMBER OF PLANTS IN 12 SYSTEMATICALLY DISTRIBUTED SAMPLE STRIPS

Pasture B

Year	Season of counting		Slender wheat grass	Timothy	Kentucky blue grass (not seeded)	Altaswede red clover	Alsike clover	Total	Annual weeds	Perennial weeds
1932	Spring	F*	5.5±1.1	28.1±2.1	—	11.3±1.1	15.4±1.6	60.3	—	—
		%	9.1	46.7	—	18.7	25.5	100		
	Summer	F	7.2±0.7	22.7±1.5	0.6±0.3	10.3±0.9	14.1±1.6	54.9	—	—
		%	13.1	41.4	1.0	18.9	26.0	100		
	Autumn	F	4.3±0.7	16.3±1.1	0.4±0.3	8.3±1.0	9.5±0.9	38.8	0.2	—
		%	11.1	42.0	1.0	21.4	24.5	100		
	Check (Unpastured)	F	8.5±1.1	22.6±1.1	0.1±0.1	9.0±0.9	13.9±1.1	54.1	0.1	0.5
		%	15.7	41.8	0.2	16.6	25.7	100		
1933	Spring	F	3.5±0.6	16.0±0.7	1.4±0.7	5.2±0.9	4.0±1.0	30.1	—	0.1
		%	11.6	53.1	4.7	17.3	13.3	100		
	Check (Unpastured)	F	6.5±0.9	14.9±1.1	0.3±0.2	5.4±0.6	6.7±0.9	33.8	—	0.3
		%	19.2	44.1	0.9	16.0	19.8	100		
	Autumn	F	1.9±0.4	15.5±0.7	1.8±0.5	4.8±0.8	4.9±0.8	28.9	0.2	0.1
		%	6.6	53.6	6.2	16.6	17.0	100		
	Check (Unpastured)	F	5.0±0.8	16.7±1.0	1.1±0.4	4.8±0.6	7.1±1.0	34.7	0.4	0.3
		%	14.4	48.1	3.2	13.8	20.5	100		
1934	Spring	F	2.7±0.4	15.6±1.8	5.6±1.1	0.9±0.6	0.7±0.5	25.5	0.3	—
		%	10.6	61.2	22.0	3.5	2.7	100		
	Check (Unpastured)	F	4.7±0.6	16.9±0.7	1.9±0.5	1.8±0.5	2.1±0.8	27.4	—	0.1
		%	17.2	61.7	6.9	6.6	7.7	100		
	Autumn	F	1.9±0.2	16.1±1.6	6.3±1.0	3.1±0.9	7.2±2.3	34.6	0.3	0.1
		%	5.5	46.5	18.2	9.0	20.8	100		

*F = frequency averages.
No counts were made on this pasture in 1931 as the plants were too dry at time of counting to make identification possible.
Dates of counts 1932—April 3, June 4, August 13.
1933—May 14 (pasture), 24 (unpastured check), August 28 (pasture and unpastured check).
1934—May 7, September 8 (pasture only).

TABLE 6.—FREQUENCY AVERAGES OF PLANTS OF VARIOUS SPECIES PER SQUARE FOOT AND PERCENTAGES AS DETERMINED BY COUNTS OF THE NUMBER OF PLANTS IN 12 SYSTEMATICALLY DISTRIBUTED SAMPLE STRIPS

Pasture C

Year	Season of counting		Brome grass	Kentucky blue grass	Alfalfa	Dutch clover	Total	Annual weeds	Perennial weeds
1931	Autumn	F*	8.0±1.6	20.9±1.5	4.8±1.1	16 1±1.5	49.8	2.4	1.2
		%	16.1	42.0	9 7	32.3	100		
1932	Spring	F	9.9±2.7	28.6±1.9	8.8±1 2	15 6±1.7	62 9	†	†
		%	15.7	45.5	13.9	24.9	100		
	Summer	F	9.1±1 6	25.1±2.2	7.7±0.9	16 1±1.1	58 0	0.5	0.6
		%	15.7	43 3	13.2	27.8	100		
	Autumn	F	10.7±1.2	22 3±1 7	6.9±0 7	8.4±0.7	48.3	0.1	1.1
		%	22.1	46 1	14.3	17.5	100		
1933	Spring	F	11.2±1 6	20.8±1 7	5 3±0 9	1 1±0 5	38.4	1.1	0 3
		%	29 2	54.2	13.9	2.8	100		
	Autumn	F	10.1±1.1	21 9±1 8	4 3±0 6	1.1±0.5	37.4	0.1	0.3
		%	26.9	58.6	11 6	2.9	100		
1934	Spring	F	13 3±1.8	26.8±1.2	3 6±0 7	none	43.7	0.1	none
		%	30 4	61.3	8 2		100		
	Autumn	F	9 8±0 9	26 3±1 3	3.6±0 5	none	39.7	none	none
		%	24 7	66.2	9.1		100		

No enclosures were placed in this pasture.
*F = frequency averages.
†Weeds were too minute for identification.
Date of counts: 1931—October 26.
1932—April 30, June 9, August 18.
1933—May 14, September 2.
1934—May 12, September 8.

TABLE 7.—FREQUENCY AVERAGES OF PLANTS OF VARIOUS SPECIES PER SQUARE FOOT AND PERCENTAGES AS DETERMINED BY COUNTS OF THE NUMBER OF PLANTS IN 12 SYSTEMATICALLY DISTRIBUTED SAMPLE STRIPS

Pasture D

Year	Season of counting		Crested wheat grass	Brome grass	Kentucky blue grass	Dutch clover	Sweet clover	Total	Annual weeds	Perennial weeds
1931	Autumn	F*	6.8±1.2	4.1±1.0	18.3±2.2	11.8±1.1	8.8±0.9	49.8	0.6	0.1
		%	13.7	8.2	36.7	23.6	17.8	100		
1932	Spring	F	2.6±0.6	6.8±1.5	20.1±1.5	15.1±1.6	6.4±1.0	51.0	—	—
		%	5.2	13.2	39.5	29.7	12.5	100		
	Summer	F	4.3±0.7	6.9±1.5	25.1±2.7	20.3±1.0	4.6±0.6	61.2	0.3	0.4
		%	7.1	11.3	41.0	33.1	7.5	100		
	Autumn	F	4.1±0.8	8.8±1.4	25.5±1.9	11.9±1.2	3.2±0.6	53.5	0.3	0.3
		%	7.6	16.5	47.7	22.3	5.9	100		
	Check Autumn (Unpastured)	F	5.0±0.7	11.3±0.9	25.1±2.6	15.1±0.9	2.4±0.5	58.9	—	0.1
		%	8.5	19.2	42.6	25.6	4.1	100		
1933	Spring	F	3.3±0.5	8.3±1.2	25.6±1.3	0.9±0.4	—	38.1	0.3	0.1
		%	8.6	21.7	67.3	2.4	—	100		
	Check (Unpastured)	F	3.0±0.6	11.5±0.9	20.3±1.3	1.7±0.4	—	36.5	0.1	—
		%	8.2	31.5	55.7	4.6	—	100		
	Autumn	F	1.8±0.4	9.4±1.0	22.8±0.9	3.7±0.7	—	37.7	0.4	0.1
		%	4.7	25.0	60.6	9.7	—	100		
	Check (Unpastured)	F	1.5±0.1	13.0±1.3	21.8±1.6	3.6±1.3	1.0±0.5†	40.9	0.3	—
		%	3.7	31.8	53.3	8.8	2.4	100		
1934	Spring	F	2.3±0.4	10.0±0.9	26.7±1.2	0.5±0.2	0.6±0.4†	40.1	0.1	—
		%	5.7	24.9	66.6	1.2	1.5	100		
	Check (Unpastured)	F	1.0±0.3	13.0±1.0	30.6±1.2	2.3±0.9	0.3±0.1†	47.2	1.8	—
		%	2.1	27.5	64.8	4.9	0.6	100		
	Autumn	F	0.5±0.2	8.8±0.9	29.0±0.9	1.5±0.5	—	39.8	0.3	—
		%	1.3	22.1	72.9	3.8	—	100		
	Check Unpastured)	F	0.6±0.3	10.8±0.8	28.0±1.2	5.3±1.9	0.5±0.2†	45.2	0.2	—
		%	1.3	23.9	61.9	11.7	1.1	100		

*F = frequency averages.
†These plants were seedlings. A few plants of Dutch clover were also seedlings.

Dates of counts: 1931—October 27 and 29.
1932—April 20, June 11, August 24 (pasture), 23 (unpastured check).
1933—May 19, 20 (pasture), 27 (unpastured check), August 28 (pasture), August 26 (unpastured check).
1934—May 12 (pasture), 19 (unpastured check).

TABLE 8.—FREQUENCY AVERAGES OF PLANTS OF VARIOUS SPECIES PER SQUARE FOOT AND PERCENTAGES AS DETERMINED BY COUNTS OF THE NUMBER OF PLANTS IN 12 SYSTEMATICALLY DISTRIBUTED SAMPLE STRIPS

Pasture E

Year	Season of counting		Crested wheat grass	Kentucky blue grass	Alfalfa	Dutch clover	Total	Annual weeds	Perennial weeds
1931	Autumn	F*	5.3±0 8	13.3±2 2	6 8±0 7	13 9±1 1	39 3±2 8	0.3	0.2
		%	13.5	33.8	17 3	35 4	100 0		
1932	Spring	F	4 4±0 7	19.1±3.2	4 9±0 5	13 1±1 3	41 5±3 9	—	—
	=	%	10 6	46 0	11 8	31 6	100 0		
	ummer	F	5 2±0.8	25 4±2 7	5 6±0 7	14 1±0 9	50 3±2 7	0.3	0.3
		%	10.3	50 5	11 1	28 0	99 9		
	Autumn	F	3.9±0 5	20 8±1 5	4 4±0 6	8 8±0 6	37 9±1 3	—	0 9
		%	10 3	54.9	11 6	23 2	100 0		
	Check (Unpastured)	F	5.8±0 9	23.9±1 9	5 7±0 6	8 3±1 0	43 7±2 4	—	0.1
		%	13 3	54 7	13 0	19 0	100 0		
1933	Spring	F	3.6±0 5	25.5±2 7	4.0±0.5	0 5±0.2	33 6±2 6	—	0.3
		%	10 7	75.9	11 9	1 5	100 0		
	Check (Unpastured)	F	6 3±0 7	21 0±1 1	5.3±0 7	0.3±0 1	32 9±1 3	0.3	0.1
		%	19 1	63 8	16 1	0.9	99.9		
	Autumn	F	3.1±0 4	22 6±1.0	3 8±0 8	1 0±0.5	30 5±1 3	0.3	0 2
		%	10.2	74.1	12 5	3 3	100 1		
	Check (Unpastured)	F	6 1±1 0	21 9±0 9	5 0±0 6	0 7±0 4	33 7±1 0	0.2	—
		%	18.1	65 0	14 8	2 1	100 0		
1934	Spring	F	2 8±0 4	38.0±0 9	0 1±0 0	—	40 9±0 7	2.5	—
		%	6 8	92 9	0 2	—	99 9		
	Check (Unpastured)	F	4.0±0.7	35.1±0 9	4.5±0 4	—	43 6±0 7	—	0.1
		%	9 2	80 5	10 3	—	100 0		
	Autumn	F	2.2±0.5	30 5±1 1	1 0±0 4	0.7±0 4	34.4±1 1	—	—
		%	6.4	88.7	2 9	2.0	100 0		
	Check (Unpastured)	F	4 1±1 1	35.4±1 1	5 4±0 5	—	44 9±1 2	—	—
		%	9 1	78 8	12 0	—	99.9		

*F = frequency averages.

Dates of counts: 1931—November 4.
1932—April 29, May 28, August 14.
1933—May 14 (pasture), 24 (unpastured check), August 29 (pasture and unpastured check)
1934—May 7 (pasture and unpastured check).

The weed species have been grouped into annuals and perennials in the tables, as the frequency of any one species was very low and therefore not significant in comparison with the counts of the plants of the seeded species. For the convenience of the reader the common and botanical names of the weeds grouped in Tables 4 to 9 are given as follows: annuals: hemp nettle, *Galeopsis Tetrahit* L.; lamb's quarters, *Chenopodium album* L.; knotweed, *Polygonum neglectum* Besser; stinkweed, *Thlaspi arvense* L.; Russian pigweed, *Axyris amarantoides* L.; cinquefoil, *Potentilla monspeliensis* L.; perennials: plantain, *Plantago major* L.; Canada thistle, *Cirsium arvense* (L.) Scop.; dandelion, *Taraxacum officinale* (Weber).

The results of plant counts supplemented by critical notes indicate quite definitely some of the limitations and some of the virtues of the six pasture mixtures studied. Since the quality of a pasture mixture is no better than the combined qualities of its constituent species, it would seem appropriate to discuss these species individually before making comments on the mixtures themselves.

TABLE 9.—FREQUENCY AVERAGES OF PLANTS OF VARIOUS SPECIES PER SQUARE FOOT AND PERCENTAGES AS DETERMINED BY COUNTS OF THE NUMBER OF PLANTS IN 12 SYSTEMATICALLY DISTRIBUTED SAMPLE STRIPS

Pasture F

Year	Season of counting		Brome grass	Alfalfa	Total	Annual weeds	Perennial weeds
1931	Autumn	F*	8.2±0 9	14.1±1 6	22.3	1.2	1.2
		%	36 8	63 2	100		
1932	Spring	F	9.4±1 1	12.3±1.0	21.7	†	†
		%	43 3	56.7	100		

*F = frequency averages
†Weeds were not counted in this pasture in 1932 as they were too small for identification.
Dates of counts. 1931—November 4, 1932—April 29.

From an examination of Tables 4 to 9 it will readily be seen that the more important species from the standpoint of maintaining the constancy of a pasture stand are brome grass and Kentucky blue grass. Alfalfa remained almost constant, except in Pasture E, in which it had disappeared almost entirely in the grazed area in 1934. All the other species, according to the data, were in a state of decline after the expiration of the second season, with complete killing out of sweet clover and later of the Dutch clover. Sweet clover being biennial would be expected to disappear at the end of the second year, but Dutch clover, being perennial, might be expected to survive for several years. The disappearance of the latter must be accounted for in some other way.

The killing out of Dutch clover in 1932 and 1933 was probably due to four main factors: (1) interspecific competition, involving shading by taller species; (2) the nature of the plant itself; (3) droughty conditions the previous fall (1932); and (4) extremely low temperatures during the winter months, combined with an inadequate snow covering. The data (Tables 6, 7 and 8) show that the decline of this species began in the late summer of 1932 and continued with almost complete killing out in the spring of 1933. This decrease was about equal in Pastures C, D and F, which contained

Dutch clover in the mixtures. Pasture C had produced very rank growths of brome grass and alfalfa, pasture E of brome and sweet clover, and pasture F of crested wheat grass and alfalfa in 1932 (Tables 15, 17, 18 and 19). Pastures C and D, it will be recalled, were not grazed in June 1932, but were cut for hay in the second week in July. Moreover, these pastures were grazed very closely until fall, after the hay crop had been removed, D by sheep and C by young bulls. Accordingly it would seem probable that the combined effects of shading and crowding by the tall-growing species followed by severe grazing the second season contributed largely to the killing of Dutch clover. Also drought and hot weather in August and September of 1932 combined with the crowding and shading effects of the taller-growing associated species may have so weakened the Dutch clover plants that they could not withstand the severity of the following winter. However, no definite proof can be given to support the view that winter temperature was the final cause of killing of this plant. Furthermore, the results (Tables 6, 7 and 8) seem to suggest that Dutch clover might only be a relatively short-lived perennial. This view finds support in the work of Roberts and Jones (*8*) in Wales, and of Fenton (*4*), in England who found Dutch clover of value in pasture mixtures in the first year of grazing only, as in subsequent years it rapidly disappeared. Accordingly, from the results obtained and the supporting evidence found in the literature the conclusion would seem justified, that Dutch clover, as a constituent of pasture mixtures under the conditions of the investigation is very short-lived and of little value over a period of more than two years.

Two other species which also proved to be very undesirable from the point of view of persistence (Tables 4, 5 and 8) are crested wheat and slender wheat grasses. Both of these species had gone out almost entirely in pastures A, B and D by the autumn of 1934; crested wheat grass seemed to have decreased less in pasture E, however, for some unaccountable reason. No work with these grasses is reported in the literature reviewed.

A very noticeable feature of pasture B was the reduction of alsike and Altaswede clovers, the former from 25·5 to 2·7% and the latter from 18·7 to 3·5% by the spring of 1934. Alsike by the end of 1932 was found localized in low lying areas in pastures A and B, where, owing to greater moisture, this plant grew better than Altaswede red clover. The decline of alsike is also reported by European workers, notably Fenton (*3*) and Stapledon and Davies (*11*); and by Hein and Vinall (*7*), working in the United States. It was only in districts where moisture was more abundant that this plant competed successfully in mixtures with red clover. For these reasons the undesirability of alsike clover in pasture mixtures, except on moist land, will be readily recognized. Altaswede red clover did not prove altogether satisfactory for permanent pasture purposes either, because of its susceptibility to winter injury and its relatively short-life (although perennial) habit.

Alfalfa showed remarkable persistence in all the pastures in which it was seeded throughout the duration of the investigation, except in pasture E, in which it decreased in the grazed area from 12·5% in the fall of 1933 to 0·2% in the spring of 1934. This sharp decrease was not nearly so marked in the unpastured check. No explanation can be given at present for this rapid deterioration of alfalfa in pasture E over the winter 1933–34, as compared with its survival in other pastures.

Timothy gave evidence of being a very persistent species, as its frequency remained almost constant, except for a slight decrease in 1933. Fenton (*3*) reports that timothy was not a success in pasture mixtures in England, it being eventually crowded out and replaced by species of *Lolium* and *Agrostis*, and by *Dactylis glomerata*. This replacement would scarcely be expected to occur in the Edmonton district owing to the semi-arid climate under which these latter species would likely be less strongly competitive.

The persistence of brome and Kentucky blue grasses is clearly brought out by the data. The point of importance here is the fact that they appear to form an association without causing any marked injury one to the other. However, Kentucky blue grass appears to be somewhat the more aggressive species, and it would be interesting to study these two grasses in association over a much longer period of time than that covered by our investigation. Kentucky blue grass, while less desirable from the standpoint of yield, as will be shown later, is an excellent turf-forming species, a fact which appears to render it a strong competitor with weeds. This is amply supported in the literature.

The counts of weeds reveal no significant changes. The number of counts would need to be greatly increased before definite changes could be fully established. Critical notes reveal, however, that weeds were kept well in check by the turf-forming brome and Kentucky blue grasses.

Yields of Herbage

The data on yields per acre were secured for pastures A, B, D and E, but not for pasture F.

The yields of green herbage were computed from the weights of green material cut at intervals from the six-feet-square areas in each of the three fenced enclosures of each pasture. The yields per acre of air-dried fodder were calculated from data on the green weights and the final weights of air-dried composite samples of herbage. It is true that these results do not properly represent the productivity of the actual pastured areas, since the enclosed areas were not subjected to actual pasturing conditions such as trampling, dropping of manure and selective defoliation. Clippings of these enclosed areas at much more frequent intervals would have given results more appropriate for the estimations of pasture yields, but the more frequent clippings were impracticable under the circumstances. Although the data obtained are not strictly applicable to the pastured areas, the authors believe that they do provide some means of comparing, in a crude way, the various mixtures with respect to their productivity.

The yield data are presented in the first four columns of Tables 10 to 13. The proportions of legumes, grasses and weeds were determined from the cut herbage by a method described earlier in this paper. The data for these proportions are given in the last three columns of the same tables.

The yields secured from the various pastures in all three harvest years were very gratifying, except those from pasture D, in both 1933 and 1934, as indicated in Tables 12 and 14. The total yields of dry herbage (Table 14) the first harvest year were, on the average, a third greater than those in the second year. This might be expected, especially from pastures A and

TABLE 10.—YIELDS PER ACRE OF GREEN AND DRY HERBAGE, ALSO PERCENTAGES OF LEGUMES, GRASSES AND WEEDS

Pasture A

Year	Cutting dates	Green weight in pounds per acre	Dry weight in pounds per acre	Percentages		
				Legumes	Grasses	Weeds
1932	July 11	27,000	8,200	46	54	None
	Aug. 30	4,600	1,800	35	65	None
	Total	31,600	10,000	Av. 40.5	59.5	
1933	June 5	8,200	2,500	22	78	Trace
	July 13	8,100	2,000	52	48	Trace
	Aug. 29	5,600	1,600	80	20	Trace
	Total	21,900	6,100	Av. 51.3	48.7	Trace
1934	June 8	7,300	2,200	38	62	None
	July 24	5,900	1,500	69	31	Trace
	Sept. 8	2,800	900	84	16	None
	Total	16 000	4,600	Av. 63 7	36 3	Trace

TABLE 11.—YIELDS PER ACRE OF GREEN AND DRY HERBAGE, ALSO PERCENTAGES OF LEGUMES, GRASSES AND WEEDS

Pasture B

Year	Cutting dates	Green weight in pounds per acre	Dry weight in pounds per acre	Percentages		
				Legumes	Grasses	Weeds
1932	July 5	20,200	6,000	37	64	Trace
	Aug. 27	4,700	2,000	30	70	Trace
	Total	24,900	8,000	Ave.33 5	67.0	Trace
1933	June 6	9,200	2,500	4	96	Trace
	July 15	6,200	2,100	31	69	Trace
	Sept. 1	2,400	800	22	78	Trace
	Total	17,800	5,400	Ave.19.0	81.0	Trace

Yield determinations were not made on this pasture in 1934.

TABLE 12.—YIELDS PER ACRE OF GREEN AND DRY HERBAGE, ALSO PERCENTAGES OF LEGUMES, GRASSES AND WEEDS

Pasture D

Year	Cutting dates	Green weight in pounds per acre	Dry weight in pounds per acre	Percentages		
				Legumes	Grasses	Weeds
1932	July 7	27,500	7,500	49	51	None
	Aug. 29	6,500	2,700	32	68	None
	Total	34,000	10,200	Av. 40.5	59.5	
1933	June 6	7,500	2,300	Trace	98	2
	July 14	3,900	1,300	3	94	2
	Aug. 30	1,400	500	1	98	1
	Total	12,800	4,100	Av. 1 3	96.7	1.7
1934	June 9	4,000	1,500	2	97	2
	July 28	2,100	900	Trace	100	–
	Total	6,100	2,400	Av- 1 0	98 5	1.0

TABLE 13.—YIELDS PER ACRE OF GREEN AND DRY HERBAGE, ALSO PERCENTAGES OF LEGUMES, GRASSES AND WEEDS

Pasture E

Year	Cutting dates	Green weight in pounds per acre	Dry weight in pounds per acre	Percentages		
				Legumes	Grasses	Weeds
1932	July 9	24,200	7,600	41	55	4
	Aug. 31	5,000	2,000	54	46	Trace
	Total	29,200	9,600	Av. 47.5	50.5	2.0
1933	June 9	10,700	3,000	33	68	None
	July 16	7,900	2,600	57	43	None
	Sept. 4	4,300	1,500	66	34	None
	Total	22,900	7,100	Av. 52 0	48.3	None
1934	June 4	7,200	2,200	32	68	None
	July 26	6,700	2,000	57	43	None
	Sept. 9	2,700	900	79	21	None
	Total	16,600	5,100	Av. 56·0	44·0	None

TABLE 14.—SUMMARY OF TOTAL YIELDS PER ACRE OF GREEN AND DRY HERBAGE FROM PASTURES A, B, D, AND E FOR 1932, 1933 AND 1934

Species and pounds of seed per acre used in the mixtures		*A*	*B*	*D*	*E*
		Brome grass . . . . . . 2.8 Crested wheat grass . 2.5 Slender wheat grass .. 0.7 Kentucky blue grass 3.0 Alfalfa. . . . . 3.0 Sweet clover. . . . . 3.0 Alsike clover . . 2.0	Slender wheat grass. . 5.0 Timothy . .. . 3.0 Altaswede red clover.. 4.0 Alsike clover . . 3.0	Crested wheat grass... 2.0 Brome grass . . . . 2.7 Kentucky blue grass. . 4.0 White Dutch clover. . 5.0 Sweet clover 3.0	Crested wheat grass.... 5.0 Kentucky blue grass... 4.0 Alfalfa. . . . . 3.0 White Dutch clover.... 2.0
Year	State of herbage	Pounds of herbage	Pounds of herbage	Pounds of herbage	Pounds of herbage
1932	green dry	31,600 10,000	24.900 8,000	34,000 10,200	29,200 9,600
1933	green dry	21,900 6,100	17,800 5,400	12,800 4,100	22,900 7,400
1934	green dry	16,000 4,600	Not taken Not taken	6,100 2,400	16,600 5,100

D in view of the crowding out of Dutch clover on the one hand, and the complete elimination of the bulky sweet clover on the other. Similarly, a further decrease in yield occurred in 1934. This decrease in 1934 was particularly marked in pasture D. The decrease in yields from the first to the second year was less marked in pastures B and E, the reason being that the former pasture contained clovers which had decreased but little, while the latter contained alfalfa which yielded even more abundantly in the second than in the first year. The pastures may be arranged in descending order of yield for the different years as follows:

1932—D, A, E, B
1933—E, A, B, D
1934—E, A, D.

It will be observed that pasture D changed from highest place in 1932 to lowest place in 1933, which place it also held in 1934. This is a particularly interesting result when compared with the results from pasture A in 1933, which also originally contained sweet clover. The comparatively higher yield from the latter in 1933 must be attributed mainly to alfalfa. It will also be noted that pasture E, which took third place in 1932, rose to first place in 1933 and remained there in 1934. This change may be accounted for on the basis of the more rapid growth of alfalfa and Kentucky blue grass. Moreover, it will also be seen that the position of pasture A remains unchanged in the order of yield from the first to the second harvest year in spite of the dying out of sweet clover. This is also attributable largely to increased growth of the alfalfa and partly to the increased proportions of Kentucky blue and brome grasses in the pasture. Pasture B changed from lowest to third place from 1932 to 1933. This may be accounted for partly by the excellent growth made by the timothy in the drier months, even though the clovers added little to the bulk of the herbage at that time of the season. This change is also partly due to the marked decline of pasture D in yield from 1932 to 1933. Pasture E varied least in yield from cutting to cutting, and from the first to the second harvest year. The decrease in its yield was only about 25%, on the average, as against 40 in A, 56 in B, and 60% in D. This indicates quite definitely that pasture E, from the standpoint of productivity alone, is more desirable than any of the other three pastures. Pasture D, on the other hand, is shown to be the most disappointing mixture of the whole group; for this reason its suitability, after the first and second crop years for Edmonton conditions, would seem to be questionable, although its yield in the first year was very high on account of the sweet clover.

If the cut herbage be regarded as hay, the corresponding yields of actual pasture would be expected to be considerably less. Wolfe (*13*) found that the cut herbage available as pasturage was from 40 to 65% of the yield of hay. Shutt, Hamilton and Selwyn (*9*), Fenton (*3*), and others, have found that yield of pastures decreases with the frequency of cutting off the herbage. The pastures herein considered were cut twice in 1932, and three times annually thereafter, except for Pasture B which was not cut at all in 1934. The frequencies of cutting in this investigation may therefore be regarded as intermediate between cutting for hay, as ordinarily practised, and cutting at short intervals to approximate conditions of actual pasture defoliation. Our yield results may be regarded

as probably greater than the true yields of pasturage and somewhat less than the yields likely to have been realized if the crops had been cut for hay. However this may be, it would seem that the yields from the various pastures may be legitimately considered comparatively as has been done above.

Changes in the Proportions of Legumes, Grasses and Weeds

Certain seasonal changes occurred in the percentages of legumes and grasses in the pasture herbage, as indicated in Tables 10 to 13.

The leguminous content of the herbage in the first cutting in 1932 was only slightly below the percentages of grasses, and was composed chiefly of sweet clover in pastures A and D, alfalfa in pasture E, and of about equal quantities of red and alsike clovers in pasture B. The second cutting in the same year revealed an increase in grasses, with a corresponding decrease in the leguminous content, except in pasture E, where leguminous herbage was in excess. This time alfalfa was the predominant legume in pasture A, and sweet clover in D. Dutch clover was present only in small quantities in D, while the grass content was chiefly brome in both. The legume content of B was two-thirds Altaswede red clover and one-third alsike clover, and the grasses were mainly timothy. The leguminous material from pasture E consisted chiefly of alfalfa, and the grass portion of about equal parts of crested wheat and Kentucky blue grasses.

The 1933 data point to somewhat different results. The legume content was quite low in the spring, but increased rapidly, until in the third cutting it greatly exceeded the grass portion, except in pastures B and D. In pasture B a marked increase in legume content was shown in the second cutting, but a decrease had again occurred by the third cutting. A similar trend was evident in pasture D, but here the proportions of legumes were very small. In pasture B the percentage of legumes was 4 and consisted of about equal parts of Altaswede red clover and alsike clover; the grass content was about 80% timothy and 20% slender wheat grass. Pasture D consisted of a trace only of legumes (entirely Dutch clover), 2% weeds and 97% grasses; the grass portion was composed, on the average, of 70% brome grass, 25% Kentucky blue grass and 5% slender wheat grass. Pasture E gave 33% legumes and 67% grasses in the first cutting; the former consisted of alfalfa with a trace of Dutch clover, and the latter was made up of 65% Kentucky blue grass with the remainder crested wheat grass.

In the herbage of the second cutting for 1933, the leguminous portions were seen to be increasing and the gramineous portions decreasing. This increase in leguminous content continued in the herbage of the third cutting, except in pastures B and D, as previously mentioned. In the second cutting of pasture A the 52% legumes was composed of 80% alfalfa and 20% alsike, and the 48% grass was mainly brome grass. In pasture B the 31% legumes consisted of two to three times as much Altaswede red clover as alsike, and the 69% grasses was about 90% timothy and 10% slender wheat grass. Pasture D yielded mainly grasses (94%) consisting of 65% brome, 25% slender wheat, and about 10% crested wheat grasses; and 2% weeds. In pasture E the 57% legume consisted entirely of alfalfa, and the 43% grasses contained 70% Kentucky blue grass and 30% crested wheat grass.

Certain interesting changes also occurred in the herbage between the second and third cuttings in 1933. In pasture A alfalfa had increased to about 97% of the leguminous content with a corresponding decrease in alsike to 3%; the grass portion consisted of 90% brome grass, 2% crested wheat grass and 8% Kentucky blue grass. In pasture B the leguminous content, which consisted of 75% Altaswede and 25% alsike clovers, showed a decrease with a corresponding increase in the gramineous herbage, which was composed of 97% timothy and 3% slender wheat grass. In pasture D the leguminous herbage, which was Dutch clover only in 1933, had decreased to 1%; the grass portion which had increased to 98% consisted of 75% brome grass, 23% Kentucky blue grass, and 2% crested wheat grass. The weed content was 1%, which indicates some decrease from the second cutting. In pasture E the increase in the proportion of legumes was somewhat less than in pasture A. This difference is due to alsike clover in the latter, whereas the former pasture contained alfalfa as the sole legume. The gramineous portion of pasture E consisted of about 85% Kentucky blue grass and 15% crested wheat grass.

In 1934 three cuttings were taken from the enclosures in pastures A and E; two cuttings were taken from pasture D, but no cuttings were obtained from pasture B. The changes in the grass-legume proportions were very similar to those noted in 1933 for the same pastures. It is to be noted, however, that the proportions of legumes in pastures A and E average higher, while the percentages of grasses are correspondingly lower, in 1934 than in either of the preceding years. This is particularly noticeable for the third cuttings in the seasons. In pasture D the herbage cut was almost entirely grass. The legume portion of pasture A for 1934 was almost wholly alfalfa with a trace of alsike; the grass portion contained about equal amounts of brome and Kentucky blue grass, with traces of crested wheat and slender wheat grasses. The legume portion of pasture E was also entirely alfalfa, except for a trace of Dutch clover; while the grass portion averaged about 73% Kentucky blue grass and about 27% crested wheat grass. For pasture D the legume portion was a trace of sweet clover, while the grass portion contained about 65% brome grass and about 35% Kentucky blue grass with traces of crested wheat and slender wheat grasses.

The comparative predominance of alfalfa, brome and Kentucky blue grasses and timothy in these pastures is particularly evident, while Dutch clover, alsike and Altaswede red clover, slender wheat and crested wheat grasses tended to become relatively less abundant from year to year, and also from spring to autumn in the different years.

The factors thought to be most effective in bringing about these changes are drought, temperature extremes, biological and mechanical factors, and the natural life periods of the plants themselves. While the changes in legume-grass proportions were undoubtedly due in large measure to the interaction of these factors, it would seem appropriate to consider them in brief separately.

The survival and prominence of alfalfa would seem to have resulted from the deeply rooted nature of the plant, thus enabling it during dry periods of the year to draw upon moisture supplies at lower depths, which were not available to the more shallow-rooted Altaswede red clover, alsike and Dutch clovers. Altaswede red clover appeared to be more drought-resistant than alsike, as might be expected, the latter being particularly

adapted to moist soil conditions. The decreases in herbage from slender wheat and crested wheat grasses were no doubt attributable to plant competition to a greater extent than to drought, since both are fairly drought-resistant. Brome grass being quite drought-resistant made fairly good growth, even in the drier months. Kentucky blue grass, though not as drought-resistant as some other grasses, appeared to have good regenerative power, as it made rapid growth after each rain. The alfalfa, brome grass and Kentucky blue grass appeared to thrive in company with one another and may possibly be regarded as forming a successful association in an ecological sense. A longer period of time would, however, be required to test the stability of this association.

Extremely low temperatures, especially in early spring, appeared to be injurious to all the clovers and alfalfa. Dutch and alsike clovers suffered the greatest injury at this time, while Altaswede red clover, sweet clover and alfalfa sustained somewhat less damage.

The biological factors affecting the proportions of legumes and grasses are inter-specific competition, shading, and probably certain internal physiological conditions induced in response to the environment. Brome grass and sweet clover made very rapid growth the second season which resulted in the creation of a so-called micro- climate[3] near the ground. This was undoubtedly injurious to Dutch clover. Injury from this cause and from shading affected also to a lesser extent the two grasses, slender wheat and crested wheat. Neither Kentucky blue grass, alfalfa nor Altaswede red clover appeared to be damaged in this way.

In late summer the three grasses, slender wheat, crested wheat and Kentucky blue, particularly the first two species, exhibited a reduced rate of growth which seriously affected their productiveness, and hence reduced their contribution to the grass portion of the legume-grass ratio. Vinall and Hein (*12*) report that this period of reduced growth occurs in most grasses coincident with, or directly after, the time of the year when these plants normally produce seed. Hence, the common belief that the reduced growth rate of plants in late summer is due to drought alone appears to be erroneous. This phase of the work will be discussed more fully in the section dealing with earliness and activity of growth.

The proportion of legumes was probably reduced in one or two cases as a result of crowding out by the tall-growing brome grass. This apparently took place in pasture D in the case of Dutch clover in 1933. The vigorous growth of sweet clover the previous year was undoubtedly also a contributing factor in crowding out the Dutch clover. The dominant character of alfalfa in this regard is clearly seen in the results from studies of pastures A and E. This species appears to exhibit very great and rapid regenerative powers. Even in the drier latter part of the season, it seemed to grow at a normal rate, which is very important from the standpoint of production of late pasturage.

Mechanical factors affecting the legume-grass ratio were: clipping, grazing and trampling by live stock. No attempts were made to study the effects of grazing and treading by the cattle on the proportions of legumes

[3] Tall growing plants such as brome grass and sweet clover alter the atmospheric conditions near the ground by excluding sunlight and by cutting down evaporation from the soil and plant surfaces. The dampness which results after a heavy rain, in the absence of sunlight, often causes decay of vegetative parts of the plant. This altered atmospheric condition near the ground surface has been referred to by some investigators as a micro-climate.

and grasses in the herbage. However, it might be inferred that grazing is not unlike cutting in its effects. The effect of cutting on the growth of grasses is clearly shown in the decrease in the quantities contributed by slender wheat and crested wheat grasses. Cutting did not seem to reduce, markedly, the proportions of alfalfa, Altaswede red clover and Kentucky blue grass.

Earliness and Periods of Active Growth

Tables 15 to 19 contain data on the various species collected at intervals during the growing season. Measurements were made on the material growing on the clipped areas within the fenced enclosures, and also on the growing plants on the pastured areas. Immediately following the measurements taken in the enclosures, the clipped areas were cut and new growth was allowed to take place for subsequent measurements.

It is generally recognized that certain species exhibit a more rapid early, continuous or late growth than others; also that certain species have a period of maximum growth and a period of relatively slower growth (Fenton *3*, *4*, and Vinall and Hein, *12*). These phenomena have an important bearing on the productivity of pasture mixtures during different periods of the growing season. It was in the hope of throwing some light on this problem that heights of plants in each pasture were measured at various times during the pasture season.

The results of these height measurements (Tables 15 to 19) indicate that, in general, the grasses were more rapid growers early in the growing season than the legumes. Brome grass was the earliest and most rapid grower in the spring, and it persisted in a state of relatively good growth in spite of repeated defoliations, until cold weather arrived. Next in earliness and persistency of growth was crested wheat grass. The growth of this species seemed to be less inhibited by drought in late summer than brome. Incidentally, this grass, where cut or closely grazed, also con-

TABLE 15. –AVERAGE HEIGHTS IN INCHES OF PLANTS OF VARIOUS SPECIES

Pasture A

Dates of measurements		Brome grass	Crested wheat grass	Slender wheat grass	Kentucky blue grass	Alfalfa	Sweet clover	Alsike clover
1932								
*May 26	Pasture	18 0	15 0	14 3	12 5	12 4	12 0	8.6
July 11	Enclosure	54 8	41 3	48 6	36 3	35 2	51 7	34.2
Aug. 30	Enclosure	19 0	15 6	13 8	11 7	16 0	19 0	5.6
1933								
May 6	Pasture	4 0	3 5	3 5	2 0	2 0	None	1.5
June 5	Enclosure	20 5	14 9	14 7	12 7	13 5	None	8.5
July 13	Enclosure	21.4	19 6	19 0	16.3	18 3	None	14 9
Aug. 29	Enclosure	11 1	6 8	10 0	8 9	16 3	None	5.8
1934								
April 28	Pasture	3.1	2 6	2 8	1 6	1 6	None	1.0
June 8	Enclosure	18 8	9.7	8.0	17.4	13 1	None	9.5
July 24	Enclosure	11 8	7.3	7.5	7.8	15 0	None	8.5
Sept. 8	Enclosure	4 8	–	–	3.3	10.4	None	2.3

*Height measurements were not taken on this pasture in the early spring of 1932.

TABLE 16.—AVERAGE HEIGHTS IN INCHES OF PLANTS OF VARIOUS SPECIES

Pasture B.

Dates of measurements		Slender wheat grass	Timothy	Altaswede red clover	Alsike clover
1932					
May 5	Pasture	3.9	4.8	1.8	2.2
June 4	Pasture	15.3	16.0	8.7	10.3
July 5	Enclosure	42.5	40.6	22.9	25.9
Aug. 27	Enclosure	17.6	21.3	8.3	9.3
1933					
May 6	Pasture	4.0	3.0	2.0	2.0
June 6	Enclosure	13.7	16.4	7.6	7.9
July 15	Enclosure	18.3	19.5	13.4	13.4
Sept. 1	Enclosure	7.9	7.5	6.1	5.6
1934					
April 28	Pasture	2.2	1.5	1.3	No growth

TABLE 17.—AVERAGE HEIGHTS IN INCHES OF PLANTS OF VARIOUS SPECIES

Pasture C

Dates of measurements		Brome grass	Kentucky blue grass	Alfalfa	Dutch clover
1932					
May 5	Pasture	6 6	4 2	3.3	2.2
June 9	Pasture	26.1	20 1	15.5	10.0
July 2	Pasture	48 1	31.4	28.1	20.8
1933					
May 6	Pasture	4 0	3.0	3.0	No growth
1934					
April 28	Pasture	3 6	2 3	2.3	None

TABLE 18.—AVERAGE HEIGHTS IN INCHES OF PLANTS OF VARIOUS SPECIES

Pasture D

Dates of measurements		Crested wheat grass	Brome grass	Kentucky blue grass	Dutch clover	Sweet clover
1932						
May 5	Pasture	7.3	7.5	3.9	2.4	2.3
June 11	Pasture	19.3	26.4	23.8	11 7	18 3
July 2	Pasture	32.0	47 3	32.3	18.5	35.0
July 7	Enclosure	37.3	50.0	36.4	21.8	45.3
Aug. 29	Enclosure	16 3	18 3	12.7	7 5	19 9
1933						
May 6	Pasture	3 5	4 0	2.0	1.0	None
June 9	Enclosure	15 0	18 2	12 3	5 3	None
July 14	Enclosure	14.7	15 6	9 7	5.7	None
Aug. 30	Enclosure	6 9	7 8	5 8	2.6	None
1934						
April 28	Pasture	2.7	3.0	1.9	No growth	None
June 9	Enclosure	10.3	13.2	12.3	3.5	None
July 28	Enclosure	8.6	8.2	4.8	4.5	None

TABLE 19.—AVERAGE HEIGHTS IN INCHES OF PLANTS OF VARIOUS SPECIES
Pasture E

Dates of measurements		Crested wheat grass	Kentucky blue grass	Alfalfa	Dutch clover
1932					
*May 25	Pasture	13 8	8 5	7 5	4 6
July 9	Enclosure	36 5	33 1	28 4	19.6
Aug. 31	Enclosure	21.7	12.1	19 1	6 4
1933					
May 6	Pasture	3.0	3 0	2.0	1.0
June 9	Enclosure	20 5	16.5	14 4	5.9
July 16	Enclosure	19 1	15 0	18 6	No growth
Sept. 4	Enclosure	8 5	7.4	11.1	No growth
1934					
April 28	Pasture	2 8	1 7	1 5	None
June 4	Enclosure	13 2	12 8	11.1	None
July 26	Enclosure	12.4	7 8	18.3	None
Sept. 9	Enclosure	4 9	3 3	10.1	None

*Height measurements were not taken on this pasture in the early spring of 1932

tinued in a state of active growth late in the fall, as evidenced by both its height and greenness of colour long after brome and slender wheat grasses had been killed by heavy frosts. Timothy was apparently the third most important grass species from the standpoint of earliness and persistency of growth. Its growth appeared to be injured less by clipping than crested wheat grass, but it proved to be more susceptible to drought injury. Kentucky blue grass fell into fourth place in activity and persistency of growth. This species while it was not as early a producer of pasturage, was nevertheless only slightly behind the other grasses in persistency of growth late in the season. In periods of drought this grass appeared dry and dead, but as soon as a shower of rain came it was observed to spring up rapidly and produce green, succulent pasturage, indicating pronounced regenerative powers. Similar observations are reported by Fink, Mortimer and Truog (*5*) and by Hein and Vinall (*7*).

The legumes, as already stated, did not make as rapid growth in the spring as the grasses. However, certain of them, particularly alfalfa, persisted in a state of active growth quite late in the summer and early fall in spite of drought. Of the legumes seeded, alfalfa is shown to have made the most rapid early and late growth. In the middle of, and late in, the season sweet clover exceeded alfalfa in rapidity of growth. Among the legumes, next to alfalfa in production of early spring growth would seem to be Dutch clover, although the difference between the latter and sweet clover in this regard (Table 18) is scarcely significant. Further work is necessary to establish this point definitely. Continued rapid growth of alfalfa late into August is also reported by Vinall and Hein (*12*). Alsike comes fourth and Altaswede red clover last in earliness of growth. In persistency and lateness of growth these clovers seem to be equal, and come third, with Dutch clover last in this regard. In 1932 sweet clover was shown to have made the greatest fall growth, far exceeding alfalfa. By 1933 the sweet clover had disappeared.

Figure 3 serves to convey some idea of the amount and rapidity of growth in 1932 for the five pastures studied.

Palatability of Various Species as Indicated by the Selectivity of Grazing Animals

This investigation was not undertaken with any intention of including observations on the relative palatability of the various species included in the mixtures. This aspect warrants a separate study. However, in taking general notes on the pastures from time to time, it was observed that plants of certain species were grazed very closely while others were left almost untouched. This led the writers to take a few critical notes on the selectivity of the grazing animals. These notes have been supplemented with photographs (Figures 4 and 5) of one pasture illustrating typical selectivity.

Observations showed that the more palatable species (those readily eaten by the cattle) were Kentucky blue grass, Dutch clover, Alfalfa, alsike clover, timothy, brome grass and Altaswede red clover, in the order named. The apparently unpalatable species (less readily eaten) were in descending order of palatability: sweet clover, slender wheat grass and crested wheat grass. The photographs (Figures 4 and 5) illustrate the high palatability of Kentucky blue grass and the apparent unpalatability of crested wheat grass. These observations are not entirely in agreement with results reported by Stapledon (*10*). He found timothy and wild white clover to rank highest in palatability among the species studied by him.

There might be objection to these conclusions on the grounds that in 1932 the species were well advanced in their growth when pasturing was begun in the spring, at which time the different species being in different stages of growth would on this account, show differential palatability. This objection would no doubt be justified. However, the authors, as a result of their observations over the three years, believe that their conclusions regarding the relative palatability of these species are not far wrong under the conditions of the investigation.

GENERAL CONCLUSIONS

The object of this investigation was to study changes that might take place in the vegetative composition of the pastures, and the relative survival and productivity of the different species in different mixture combinations.

It may be well to point out that the results obtained have not been presented with the idea that they are conclusive or that the objects of the investigation have been fully realized. Certain of the results do, however, appear to be significant; for example, changes in the floral composition of the pasture mixtures were very evident. Certain species were found to possess short survival value while others persisted under the conditions of the investigation, and considerable variability was exhibited in the productivity of different mixtures and difference species. Brome, Kentucky blue grass and alfalfa appeared to be the most valuable perennial species used in the mixtures, from the standpoints of persistence, adaptability and productiveness. Alsike clover, Altaswede red clover, Dutch clover, crested wheat and slender wheat grasses were less persistent and less productive. Observations on palatability indicated that Kentucky blue grass, Dutch clover, alfalfa and alsike clover were the more palatable species, while slender wheat and crested wheat grasses were the least palatable, with other species being intermediate.

FIGURE 1 A test strip area The flat stakes shown are two inches wide, are placed feet apart and mark off strip-areas in the pasture for periodic counting of plants.

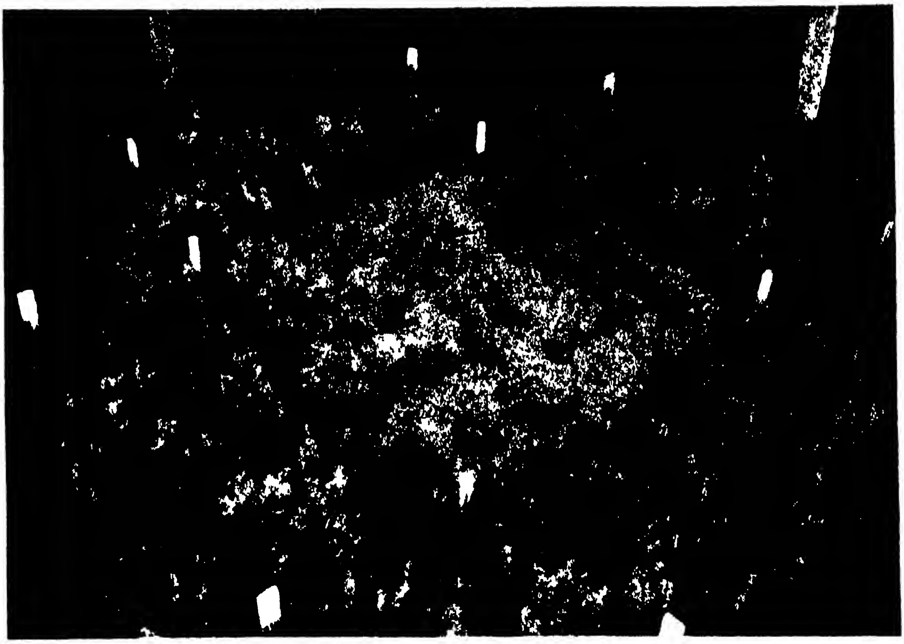

FIGURE 2. A test enclosure. The flat stakes shown are six feet apart and mark off strips for the periodic counting of plants. The central area is six feet square, and was cut for yield determinations.

FIGURE 3 The sheaves shown represent composite samples drawn from the cut herbage of each of the five pastures when the first cutting was taken in 1932. They serve to illustrate in a general way the botanical composition of each pasture mixture, and the relative heights of constituent plants at the time of cutting

The dates of cutting and heights in inches of sheaves are as follows

Pasture	*Date of cutting*	*Maximum height in inches*
A = I	July 13	48
B = II	July 16	46
C = III	July 13	53
D = IV	July 16	52
E = V	July 16	36

FIGURE 4 A photograph illustrating the selectivity of cattle in grazing. The ungrazed grass is crested wheat grass. The photograph was taken of a spot chosen at random in pasture E on October 11, 1933

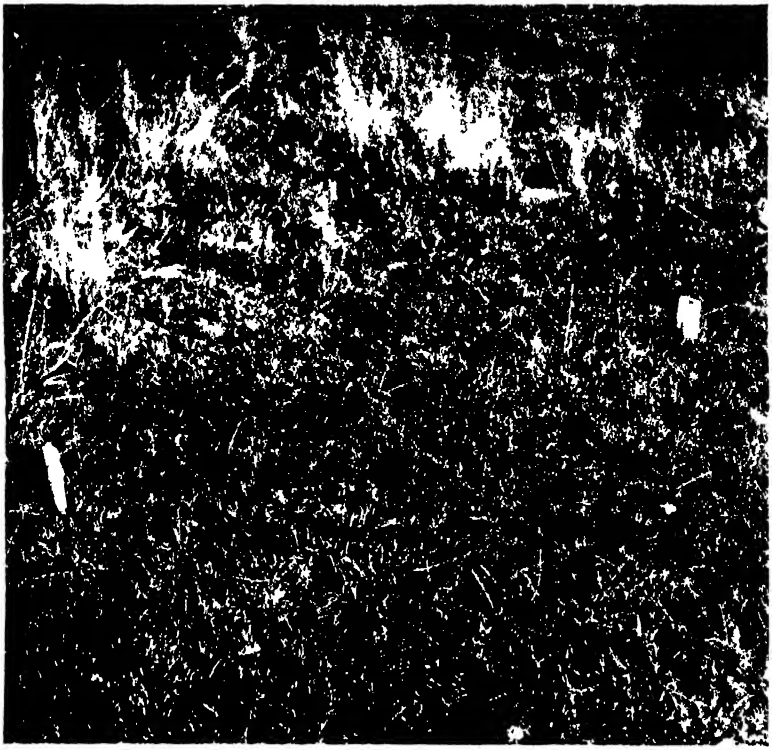

FIGURE 5 The photograph illustrates the close grazing of Kentucky blue grass and alfalfa, and the avoidance of crested wheat grass The stakes shown are approximately 4 inches above the ground level The photograph was taken of one of the strip-areas in pasture E on October 11, 1933.

The data presented and the general observations would seem to suggest that brome would be an excellent pasture grass in areas of periodic drought, similar to those common to Edmonton. Crested wheat grass is apparently not well suited to pasture mixtures, even though it is highly drought-resistant, as repeated defoliations seemed to cause its rapid killing out. Moreover, cattle avoid grazing it almost entirely, except in the spring and early summer when all growth is tender and succulent. Timothy was injured less by clipping than crested wheat grass, but it proved to be more susceptible to drought. On the whole, it is much to be preferred to crested wheat grass in mixtures for pastures for our conditions. Slender wheat grass did not give promise of a good or even fair pasture grass, as it declined rapidly with repeated defoliations, and it appeared to be exceeded in unpalatability by crested wheat grass only. Kentucky blue grass gave indications of being a very desirable constituent of pasture, due to its colonizing and regenerative powers and its high palatability. Of the legumes, alfalfa appeared to be particularly suitable for pasture, although some deterioration occurred, probably due to winter killing and possibly to crowding. Sweet clover was found to be of value only in the first harvest year. Altaswede red clover is undoubtedly better suited for hay than for pasture. Alsike clover appears to be a good pasture species where the land is low and damp. It does not compete successfully with Altaswede on higher ground. Dutch clover was the most disappointing of all the legumes because of its complete killing out in the third year.

Pasture C undoubtedly represents a good mixture. More care should be exercised in the method of seeding brome grass, however. Replacement of the white Dutch clover by three pounds of alsike clover seed per acre is suggested. Pastures A and E have been shown to be almost equal in regard to productivity and quality of herbage, with the balance in favor of E. It should be recalled here (see Table 8), however, that alfalfa in pasture E had been almost completely killed out in 1934 in the pasture proper, while in the enclosures it still survived.

The results from Pasture B are not as indicative of high productivity and quality of pasturage as might be expected. It seems doubtful if alsike and Altaswede clovers in mixtures with grasses are desirable constituents of pastures. The need for alfalfa in the mixture was brought out clearly in the results. Also timothy became very fibrous and brown in appearance in August unless pastured very closely. The studies on pasture F showed that alfalfa and brome grass grow well together, and the former was not markedly injured by continuous grazing in this pasture. A general thickening of the stand had occurred by 1934.

The weed flora appeared to have been reduced in all the pastures, except in pasture E in 1934, when Russian pigweed had increased markedly and had occupied all former bare areas and paths. An explanation for its presence is not evident. Apparently the seeds had been dormant in the soil since before seeding in 1931. Few weeds were observed to have gone to seed in the other pastures.

The most outstanding results of the investigation were, perhaps, the gradual disappearance of both slender wheat and crested wheat grasses, and the almost complete killing out of Dutch clover. The contribution by these two grass species to the grass portion of the legume-grass ratio was at no time more than barely significant, indicating that their dis-

appearance does not alter markedly the productivity of the mixtures in which they were included. A second striking result is the apparent amicable growing relations between brome grass, Kentucky blue grass and alfalfa.

The determination of a pasture mixture or mixtures suitable to existing conditions of soil and climate in the Edmonton district is obviously of great economic importance to farmers. Hitherto, no such mixture has been available and no work has been reported in Canada, so far as the writers are aware, which offers any dependable guidance. The results of these investigations may serve as some guide in compounding perennial pasture mixtures for conditions similar to those of the Edmonton district.

SUMMARY

1. The better seed mixtures for perennial pastures were those containing alfalfa, brome grass and Kentucky blue grass. These species were characterized by high productivity, high palatability, amicable growth association with one another, and by strong resistance to drought, cold and defoliation. The poorer, short-duration mixtures contained sweet clover and Dutch clover, but no alfalfa.

2. Dutch clover had disappeared almost completely by the beginning of the third season after seeding. This was believed to be due mainly to the shading and crowding effects of the tall-growing brome grass and sweet clover.

3. Altaswede red clover had decreased less than alsike clover. Both of them, however, showed rapid decreases in frequency. These plants, under the conditions of the investigation, were not entirely satisfactory pasture species. This is believed to be due to their sensitivity to adverse factors, e.g., drought and plant competition.

4. Slender wheat grass showed rapid decreases in its frequency from 1932 to 1934, due, probably, to the injurious effect of repeated defoliations and the apparently short-life duration of this species. Crested wheat grass also showed rapid decreases in its frequency, except in pasture E, where its decrease was less marked. This species also proved to be comparatively unpalatable. Thus it would seem that these species are not very satisfactory for pasture purposes in the Edmonton area.

5. Timothy, while it was not injured by drought and repeated defoliations, appeared to be more suitable as a hay than as a pasture plant, as indicated by its rank culm growth, and its tendency towards head production.

6. Sweet clover was of value in the mixture only up to the middle of the second summer because of its biennial habit of growth, and the dry conditions in the latter part of this season. The objectionable features of this plant for pasture purposes were its coarseness and short-life period.

7. Weeds were kept well in check and appeared to be decreasing in frequency, except in pasture E in 1934, where the frequencies of weeds had increased. Stinkweed was very troublesome in the first year, but it showed a rapid decrease from year to year.

REFERENCES

1. CAMP, B. H. The Mathematical Part of Elementary Statistics. D. C. Heath and Company, New York. 1931.
2. DAVIES, W. Methods of pasture analysis and fodder sampling. Welsh Plant Breed. Sta. Rept. 1, 19 pp. (mimeographed). 1931.
3. FENTON, E. W. A botanical study of pasture plots. Ann. Appl. Biol. *17* : 522-548. 1930.
4. ————. A botanical study of pasture formation. Ann. Appl. Biol. *18* : 334-351. 1931.
5. FINK, D. S., MORTIMER, G. B. and TRUOG, E. Three years results with an intensively managed pasture. Jour. Amer. Soc. Agron. *25* : 441-453. 1933.
6. GOULDEN, C. H. Statistical methods in agronomic research. Plant Breeders' Series, Publ. No. 2. Can. Seed Growers' Assoc., Ottawa. 1929.
7. HEIN, M. A. and VINALL, H. N. Persistence of grass and legume species under grazing conditions. Jour. Amer. Soc. Agron. *25* : 595-602. 1933.
8. ROBERTS, R. A. and JONES, W. A. Some studies in pasture establishment. Welsh Jour. Agr. *5* : 117-126. 1929.
9. SHUTT, F. T., HAMILTON, S. V. and SELWYN, H. H. The rotational or close-grazing system of pasture managements. Jour. Agr. Sci. *22* : 647-656. 1932.
10. STAPLEDON, R. G. Four addresses on the improvement of grassland. I. Points of view relative to the study of grassland. Welsh Plant Breed. Sta. (Unnumbered publication). 1933.
11. ———— and DAVIES, W. Sensible seed mixtures: seed mixture problems: Competition. Welsh Plant Breed. Sta. Bul. Ser. H, No. 8. 1928.
12. VINALL, H. N. and HEIN, M. A. Seasonal production of grasses and legumes at Beltsville, Maryland, in 1931. Jour. Amer. Soc. Agron. *25* : 588-594. 1933.
13. WOLFE, T. K. The yields of various pasture plants at different periods when harvested as pasturage and as hay. Jour. Amer. Soc. Agron. *18* : 381-384. 1926. Exp. Sta. Record *55* : 827. 1926.

Résumé

Une étude botanique des mélanges à pâturages. W. C. Stone et J. R. Fryer Université de l'Alberta, Edmonton, Alberta.

Les meilleurs mélanges de semences pour les pâturages vivaces sont ceux qui contiennent de la luzerne, du brome inerme, et du pâturin bleu du Kentucky. (Pâturin des prés). Ces espèces se sont caractérisées par une haute productivité, une bonne succulence, une bonne tolérance végétative les unes envers les autres et une haute résistance à la sécheresse, au froid et à la défeuillaison. Les mélanges plus pauvres, de courte durée, contenaient du mélilot et du trèfle de Hollande, mais pas de luzerne. Le trèfle de Hollande avait disparu presque complètement vers le commencement de la troisième saison après les semailles. On attribue cette disparition en grande partie à l'ombrage et à l'effet étouffant exercé par le grand développement du brome inerme et du mélilot. Le trèfle rouge Altaswede a diminué moins que le trèfle d'alsike. Tous deux, cependant, montrent des diminutions rapides de fréquence. Dans les conditions de cette enquête ces plantes ne se sont pas montré très bonnes pour le pâturage. On croit que c'est à cause de leur sensibilité aux facteurs adverses comme la sécheresse et la concurrence faite par les autres plantes. L'agropyre grêle (Ray-grass de l'Ouest) a exhibé des diminutions rapides de fréquence de 1932 à 1934, sans doute à cause de l'effet nuisible des défeuillaisons répétées et de la durée apparemment courte de cette espèce. L'agropyre à crête exhibait aussi des diminutions rapides de fréquence, sauf dans le pâturage "E" où sa diminution était moins marquée. Cette plante s'est aussi montrée assez peu savoureuse et c'est pourquoi il semble que ces espèces ne sont pas très satisfaisantes pour les pâturages dans la région d'Edmonton. Le mil, qui cependant n'a pas été affecté par la sécheresse et les défeuillaisons répétées, paraît faire une meilleure plante à foin qu'à pâturage, ainsi que l'indique la végétation épaisse de ses tiges et sa tendance à la production des épis. Le mélilot n'était utile dans les mélanges que jusqu'au milieu du deuxième été à cause de son mode bisannuel de végétation et des conditions de sécheresse pendant la dernière partie de la saison. Les désavantages de cette plante pour le pâturage sont sa grossièreté et son peu de durée. Les mauvaises herbes ont été bien tenues en échec et leur production paraissait décroître, sauf dans le pâturage "E" en 1934 où leur fréquence avait augmenté. Le tabouret a causé beaucoup d'ennui la première année, mais il a diminué rapidement depuis lors d'une année à l'autre.

PHYSIOLOGIC SPECIALIZATION IN *PUCCINIA CORONATA AVENAE*[1]

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INTRODUCTION

Crown rust of oats (*Puccinia coronata Avenae* Erikss. and Henn.) occurs to some extent in Canada almost wherever oats are cultivated. It is of considerable economic importance in Eastern Canada, where it often causes severe losses. In Manitoba and Saskatchewan, it usually does not cause appreciable damage, except where oats are grown in proximity to buckthorn (*Rhamnus cathartica* L.) hedges, but in 1927 it did occur in epidemic form in these two provinces. It is of very minor importance in Alberta and British Columbia.

Hoerner (*1*), who was the first to demonstrate physiologic specialization in *P. coronata Avenae*, isolated four forms in 1919. He distinguished these forms by the types of infection that they produced on two differential oat varieties, Ruakura and Green Russian. A few years later, in 1926, Popp (*8*) isolated four forms of crown rust from collections obtained in Eastern Canada. He could not determine definitely whether or not the forms which he isolated were similar to those reported by Hoerner, as he was not certain that the strain of Ruakura which he used was identical with the strain of that variety used by Hoerner. In 1927, Parson (*5*) studied collections of crown rust, which he obtained from various localities in the United States, and succeeded in isolating five distinct physiologic forms. The differential hosts which Parson used differed from those used by Hoerner and by Popp, and consequently he was unable to compare the forms which he isolated with those reported by them. Using a set of differential hosts, which included all the varieties used by these workers, the writer (*7*), in 1929, isolated eight physiologic forms of crown rust. Five of these forms differed from the forms reported earlier. In the same year Frenzel (*2*) isolated thirty-five forms of crown rust of oats from collections made in Germany, and Murphy (*3*), nine forms from collections made in the United States. Later, Murphy (*4*) isolated 33 physiologic forms of crown rust of oats from collections obtained in the United States, Canada and Mexico. He showed that the 33 forms identified by him embraced all the forms that had been isolated by Hoerner, Popp, Parson and Peturson, and proposed a standardized numerical designation for the 33 forms.

Unfortunately, no standard set of differential hosts has, up to the present, been generally adopted by those engaged in the identification of physiologic forms of crown rust of oats, as has been done with so much advantage in studies of physiologic specialization in both stem rust of wheat and of oats. With a view of remedying, at least partially, this

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situation, Dr. H. C. Murphy, who is in charge of crown rust investigations for the United States Department of Agriculture, and the writer agreed in 1931 to adopt a standard set of differential hosts for the identification of physiologic forms of crown rust in the United States and Canada. Table 1 gives the list of differential varieties selected.

TABLE 1.—LIST OF DIFFERENTIAL VARIETIES

Avena byzantina		*Avena sativa orientalis*	
Sunrise	C.I. 982	Green Mountain	C.I. 1892
Belar	C.I. 2760	White Tartar	C.I. 551
Red Rustproof	C.I. 1815		
Sterisel (Sterilis Selection)	C.I. 2991		
Avena sativa		*Avena strigosa*	
Ruakura Rustproof	C.I. 2025	Glabrosa	C.I. 2630
Green Russian	C.I. 2890		
Anthony	C.I. 2143		
Hawkeye	C.I. 2264		

The present study deals with the identification, prevalence, and geographic distribution of physiologic forms of crown rust of oats isolated from collections of crown rust obtained in a number of widely separated localities in Canada.

FIELD AND LABORATORY STUDIES

Identification of Forms

The various physiologic forms of crown rust of oats are apparently identical morphologically, and, as with the other cereal rusts, their identification is based on the types of infection which they produce on a set of oat varieties selected as differential hosts. In differentiating the physiologic forms of crown rust, the classes of host reactions and types of infection described by Stakman, Bailey and Levine (*9*) for stem rust of oats have been used.

An analytical key for the identification of all the physiologic forms of *P. coronata Avenae* which have been isolated in the present study is given in Table 2.

TABLE 2.—ANALYTICAL KEY FOR THE IDENTIFICATION OF PHYSIOLOGIC FORMS OF *Puccinia coronata Avenae* DETERMINED ON THE BASIS OF THEIR PARASITIC BEHAVIOUR ON DIFFERENTIAL VARIETIES WITHIN THE GENUS *Avena*.

Glabrosa susceptible	
Green Russian susceptible	Form 24
Green Russian resistant	A
Glabrosa resistant	
Green Russian susceptible	
Ruakura susceptible	
Green Mountain susceptible	1
Green Mountain resistant	10
Ruakura resistant	
Red Rustproof resistant	3
Red Rustproof susceptible	6
Green Russian resistant	
Belar susceptible	
Ruakura susceptible	4
Ruakura resistant	
Red Rustproof susceptible	5
Red Rustproof resistant	B
Belar resistant	
Green Mountain susceptible	9
Green Mountain resistant	2

In the analytical key presented here, certain differential varieties were omitted. The reason is, that their reactions are identical with those mentioned in the key. Green Russian gives the same reactions as Anthony, Green Mountain as White Tartar, and Red Rustproof as Sterisel and Sunrise. Hawkeye is omitted as it is susceptible to all of the eleven forms.

During the first year of the investigation, forms were identified at ordinary greenhouse temperature. While the work was in progress considerable fluctuations in temperature occurred from time to time. In 1930 the writer (*6*) showed that the types of infection produced by some of the forms on certain of the differential hosts were greatly modified by the temperature at which the cultures were kept during the period of incubation. He found that the types of infection produced by forms 1 and 3 were not appreciably modified by temperature, but that the infection type produced by form 4 (form 6 of the present system of classification) on Red Rustproof was slightly modified by temperature, and that the infection types produced by form 7 (form 4 of the present system) on Green Russian, Green Mountain and White Tartar varied from a O-type at 57° F. to a 4-type at 77° F. It seemed therefore highly desirable that for the identification of forms the differential hosts be kept during the period of incubation at approximately the same temperature. Consequently, in all subsequent work an attempt was made to maintain a moderately uniform temperature. The rust reactions recorded in this paper for the differential varieties are those produced at a temperature within the range of 60° to 65° F.

During the six-year period, 1929 to 1934, five hundred and forty-four collections of crown rust of oats, obtained from various localities in Eastern and Western Canada, were studied in the greenhouse. From these collections eleven distinct physiologic forms were isolated. The reactions of the differential varieties to all the forms isolated in the present study are given in Table 3.

TABLE 3.—THE REACTIONS AT 60°–65° F. OF THE ELEVEN DIFFERENTIAL VARIETIES TO THE ELEVEN PHYSIOLOGIC FORMS OF CROWN RUST ISOLATED IN CANADA

Differential host	Physiologic form										
	1	2	3	4	5	6	9	10	24	A	B
Hawkeye, C.I. 2264	4	4	4	4	4	4	4	4	4	4	4
Green Russian, C.I. 2890	4	0	4	0	0	4	2	4	4	0	0
Anthony, C.I. 2143	4	0	4	0	0	4	2	4	4	0	0
Green Mountain, C.I. 1892	4	0	4	0	0	4	4	1	4	0	0
White Tartar, C.I. 551	4	0	4	0	0	4	4	1	4	0	0
Ruakura, C.I. 2025	4	0	0	4	0	0	1	4	0	0	0
Sterisel, C.I. 2991	4	0	0	4	4	4	1	4	0	0	0
Red Rustproof, C.I. 1815	4	0	0	4	4	4	1	4	0	0	0
Sunrise, C.I. 982	4	0	0	4	4	4	1	4	0	0	0
Belar, C.I. 2760	4	0	0	4	4	4	1	4	0	0	4
Glabrosa, C.I. 2630	0	0	0	0	0	0	0	0	4	4	0

Prevalence of Forms

As already stated, collections of crown rust were obtained from different parts of Canada during the years 1929 to 1934. Table 4 gives for each of these years the number of isolations made of each form. It will be seen that some of the forms were of common occurrence and recurred year after year, while others were rare or only appeared for one season.

TABLE 4.—THE NUMBER OF ISOLATIONS OF EACH FORM MADE EACH YEAR DURING THE PERIOD 1929 TO 1934

Physiologic Form	Year						Total
	1929	1930	1931	1932	1933	1933	
	Number of isolations						
1	38	24	32	28	8	14	144
2	2	22	14	24	15	15	92
3	32	52	24	18	26	10	162
4	3	5	23	20	4	20	75
5	0	0	1	0	0	0	1
6	10	13	4	4	11	0	42
9	3	0	0	0	0	0	3
10	15	0	0	0	0	0	15
24	0	1	3	2	0	1	7
A	0	0	0	0	2	0	2
B	0	0	0	0	1	·0	1
Total	103	117	101	96	67	60	544

Distribution of Forms

The geographic distribution of the physiologic forms of crown rust of oats identified during the period 1929-34 is given in Table 5.

Table 5 shows that some of the forms occurred both in Eastern and Western Canada, while others occurred only in the one or the other of these geographic divisions. The most prevalent forms, namely, forms 1,

TABLE 5.—THE RELATIVE PREVALENCE OF PHYSIOLOGIC FORMS IN EASTERN AND WESTERN CANADA EXPRESSED IN PERCENTAGES OF TOTAL COLLECTIONS IDENTIFIED FROM EACH REGION DURING THE PERIOD 1929–1934

Physiologic form	Western Canada						Eastern Canada					
	1929	1930	1931	1932	1933	1934	1929	1930	1931	1932	1933	1934
	Percentage						Percentage					
1	39.7	37.5	49.1	43.6	18.6	38.7	28.0	0.0	9.0	9.7	0.0	6.8
2	0.0	1.5	3.5	3.6	0.0	0.0	8.0	39.8	27.2	53.6	62.5	51.7
3	25.6	40.6	8.8	12.8	44.2	0.0	48.0	49.1	43.3	26.9	29.2	34.5
4	3.9	4.7	35.0	34.6	9.3	61.3	0.0	3.7	6.8	2.5	0.0	3.5
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0
6	8.9	15.7	1.8	5.4	25.6	0.0	12.0	5.5	6.8	2.5	0.0	0.0
9	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	19.4	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	1.8	0.0	0.0	0.0	0.0	1.8	2.3	4.8	0.0	3.5
A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	8.3	0.0
B	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2, 3, 4, and 6 belong to the first-mentioned group. The relative prevalence of these forms varied considerably from year to year, but, in general, forms 1 and 4 were much more common in Western than in Eastern Canada, while the converse is true of form 2. Forms 3 and 6 were about equally prevalent in both areas.

SUMMARY

1. Eleven physiologic forms of crown rust of oats have been isolated from collections of this rust obtained in various parts of Canada.

2. Several of the forms were of common occurrence and were present year after year while others were quite rare.

3. The commonly-occurring forms were collected both in Eastern and Western Canada. Certain forms predominated in the East while others were more prevalent in the West.

LITERATURE CITED

1. HOERNER, G. R. Biologic forms of *Puccinia coronata* on oats. Phytopath. *9* : 309-314. 1919.
2. FRENZEL, HELMUT. Beiträge zur Spezialisierung des Haferkronenrostes *Puccinia coronifera* f. sp *Avenae.* Kleb. Arb. Biol. Reichsanst. f. Land-u. Forstwirtschaft *18* : 153-176. 1930.
3. MURPHY, H. C. Physiologic specialization in *Puccinia coronata Avenae.* Phytopath. *20* : 143. 1930.
4. ———————. Physiologic specialization in *Puccinia coronata Avenae.* U.S. Dept. Agr. Tech. Bul. 433. 1935.
5. PARSON, H E. Physiologic specialization in *Puccinia coronata Avenae.* Phytopath. *27* : 783-790. 1927.
6. PETURSON, B. Effect of temperature on host reactions to physiologic forms of *Puccinia coronata Avenae.* Sci. Agr. *11* : 104-110. 1930.
7. ———————. Physiologic specialization in *Puccinia coronata Avenae.* University of Minnesota. 1929. (Unpublished Thesis.)
8. POPP, Wm. Crown rust of oats in Eastern Canada. Ann. Rept. Que. Soc. Prot. Plants *18* : 383-53. 1926.
9. STAKMAN, E. C., M. N LEVINE, and D. L. BAILEY Biologic forms of *Puccinia graminis* on varieties of *Avena* spp. Jour. Agr. Res. *24* . 1013-1018. 1923.

Résumé

Spécialisation physiologique dans puccinia coronata avenae. B. Peturson, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

Onze formes physiologiques de rouille couronnée de l'avoine ont été isolées des collections de cette rouille obtenues dans différentes parties du Canada.

Plusieurs de ce formes sont bien connues et reviennent tous les ans, tandis que d'autres sont très rares. Les espèces qui se rencontrent fréquemment ont été recueillies dans l'Est aussi bien que dans l'Ouest du Canada. Certaines formes prédominaient dans l'Est, tandis que d'autres étaient plus répandues dans l'Ouest.

THE "SEEDS" OF THE GENUS POA COMMONLY FOUND ON THE MARKET IN CANADA

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The object of this paper is not to give detailed descriptions of the "seeds" of the four species of Poa which are commonly found in commerce, but rather to point out those characters which may be most readily used by the seed analyst for distinguishing the species. Very careful descriptions have been made by Hillman[2] and others.

There are four species of Poa of commercial importance in Canada

1. *Poa pratensis* L. (Kentucky Blue Grass, Smooth-stalked Meadow Grass).
2. *Poa compressa* L. (Canada Blue Grass, Flat-stalked Meadow Grass).
3. *Poa trivialis* L. (Rough-stalked Meadow Grass).
4. *Poa nemoralis* L. (Wood Meadow Grass).

There is one other species, *Poa annua* L. (Annual Blue Grass or Meadow Grass), samples of which are occasionally found in the trade. It also appears as an occasional impurity in other grasses. In spite of the fact that it is considered by many turf growers to be an undesirable grass, there are occasional demands for the seed.

There is little difficulty in the identification of these species in pure bulk lots. The trouble arises when the seeds of these grasses appear as mixtures. The cheaper Canada Blue Grass is sometimes used as an adulterant of Kentucky Blue Grass. Three or four species are frequently found together in the higher-class lawn grass mixtures, so that it is necessary to make separations in order to determine the grade of the mixture under the Seeds Act.

Such characters as the extent of the basal web, pubescence, and length of rachillae, are not satisfactory. In commercial seeds the web and pubescence are often wanting, having been removed in the process of threshing and cleaning. There is one exception to this statement. The rachillae of *Poa nemoralis* are always more or less hairy. This seems to be a constant character and one which may be used to distinguish this species from the other three. The length of the rachilla can be used to a certain degree in combination with other characters, but naturally the variation in different seeds is very great. In *P. trivialis* and *P. nemoralis* a large proportion of rachillae of over one-half the length of the caryopsis may be found.

Colour can be used only to a limited extent as a distinguishing characteristic. When compared in quantity the seeds of *P. pratensis* generally appear to be darker than the others. *P. trivialis* is a little darker than either *P. compressa* or *P. nemoralis*. When determining the percentage

[1] Chief Seed Analyst.
[2] The Seeds of the Blue Grasses, E. Brown and F. H. Hillman, U.S.D A. Bulletin 84, 1905.

of species persent in mixtures of *P. compressa* and *P. pratensis*, colour can be made use of as an assistance to identification especially when seeds of the upper florets are in question, or other seeds in which the teeth on the veins of the paleae are not exposed. *The seeds of Poa compressa are generally darker in colour toward the apex while those of Poa pratensis are generally darker at the base.*

The characters which are most useful for identification are:

(1) The "teeth" on the veins of the paleae. These teeth are stiff hairs. Hillman describes the veins or keels of the paleae as being "hispidcilliate".

(2) The characters of the lemmas.

(3) Presence of pubescence on the rachillae.

(1) The Teeth on the Veins of the Paleae

Poa pratensis: Conspicuous, broad at the base, well separated. (Figure 1, A.)

Poa compressa: Finer, close together especially towards the tips of the paleae. (Figure 1, B.)

Poa trivialis: Apparently often wanting, at least under lower power lens—always very small. (Figure 2, A.)

Poa nemoralis: Always present, very fine and hard to see unless the light is catching the seed correctly. (Figure 2, B.)

(2) Characters of the Lemmas

P. pratensis: Sharply keeled; lemma larched (side view); *intermediate veins generally distinct*, especially when the seed is lying on its side; apex acute, margins not markedly infolded, only partially covering the veins of the palea. (Figure 3.)

Poa compressa: Not sharply keeled; lemma not markedly arched (side view); *intermediate veins indistinct or wanting*, however, in occasional seeds they are quite marked; apex generally obtuse with margins widely spreading. (Figure 4.)

P. trivialis: Sharply keeled; lemma very strongly arched (side view); *intermediate veins very distinct*, particularly when seed is lying on its side; apex sharply pointed; margins of lemma infolded covering the veins of the palea often over half its length (Figure 5.)

Poa nemoralis: Not so sharply keeled; lemma not strongly arched (side view); intermediate veins almost wanting; apex acute; margins of lemma very much infolded. (Figure 6.)

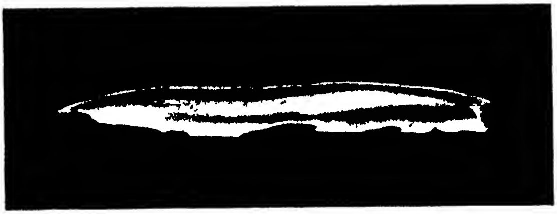
(3) Pubescence of Rachilla

A constant character of P. nemoralis only: often very short on the long rachillae of the upper florets when it might be described as puberulence. (Figure 6.)

The analyst who has the opportunity of frequently examining these seeds will, to use Hillman's words, "get his eye in" and identify the species with remarkable accuracy by general appearance, using special characters when in doubt. The less experienced analyst will probably use the characters of the "teeth" as a very sure means of identification in combination

A
FIG. 1—Poa pratensis.

B
FIG. 1—Poa compressa.



A
FIG. 2—Poa trivialis.

B
FIG. 2—Poa nemoralis.

Fig. 3—Poa pratensis

Fig. 4—Poa compressa.

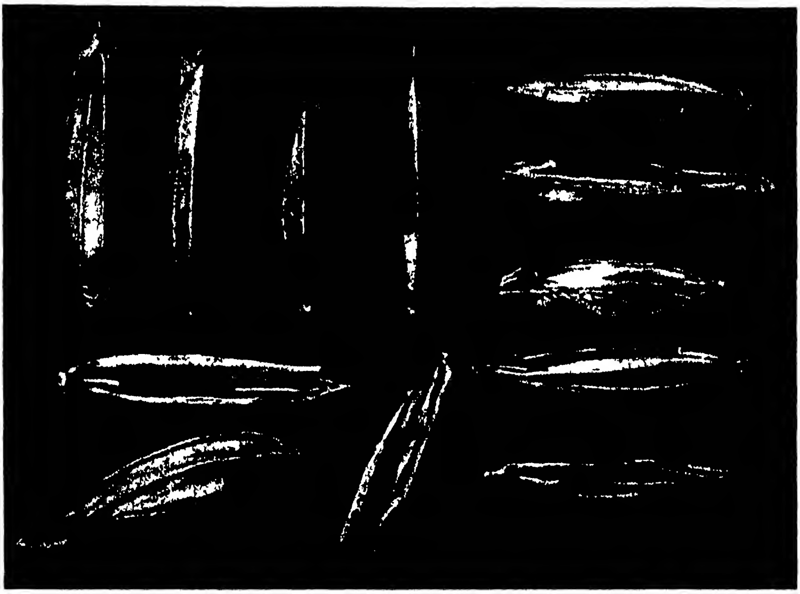


Fig. 5—Poa trivialis

Fig. 6—Poa nemoralis.

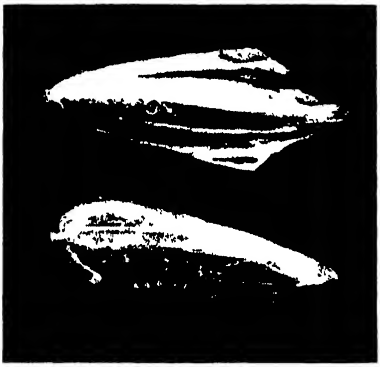


FIG. 7—Poa annua.

with the distinctness of the intermediate veins, etc. Seeds such as those shown in Figure 3x and Figure 4x are difficult to distinguish by the general appearance and the intermediate veins. Figure 4x shows a quite sharply pointed type of *P. compressa* which has the intermediate veins much more sharply defined than is normal. The teeth on the palea would be the determining factor in this case.

Poa Annua. The "seeds" of Poa annua (Figure 7) are quite characteristic, so much so that there should be no difficulty in distinguishing them from the four species already mentioned. They are robust, strongly keeled and arched. The keels and marginal veins of the lemmas are more or less densely pubescent. The intermediate veins are very distinct and are sometimes pubescent, as is also the surface between the veins. The lemmas are very narrowly infolded below the middle, broadly hyaline above, and flaring. The keels or veins of the palea are coarse and densely pubescent, much arched and exposed from side view.

NOTE: Drawings approximately 14 times size of seed.

A STUDY OF THE CAUSES OF "BLAST" IN OATS

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[Received for publication August 1, 1935]

The term "blast", as related to oats, has been given to a type of sterility commonly found in this crop and which presumably reduces the yield considerably. Oat blast manifests itself at the time of heading in the form of white, empty glumes particularly towards the base of the panicle. Sterility of this type has been reported by many workers under various terms, e.g., "blight", "blindness", "white ear", "blast", etc.

Among earlier reports on oat blast, the generally accepted opinion appeared to be that the injury was caused by insects. This conclusion was arrived at by workers both in Europe and America. In 1914, Hewitt (*7*) reported that sterility of this form was the result of injury caused by the grass thrip. Hewitt, in this paper briefly reviews the observations of several European workers who had found thrips responsible for spikelet injury in cereal crops. It is possible that the type of sterility referred to by these earlier workers did not conform to the injury now commonly called blast, although from descriptions given, it would seem to be identical.

Manns (*10*) working on blade blight of oats observed that there was close agreement between blasted spikelets and extent of blade blight. He pointed out that some blasted spikelets may be caused directly by a blight organism but that more often this sterility is brought about by reduced vitality of the plant as a result of blade blight.

Elliott (*3*) working with the halo blight organism, found no relation between this disease and the prevalence of blast. She concluded that sterility, known as "blast", was brought about by the presence of "too much moisture about developing panicles". This author also observed that varieties of oats possessed different amounts of sterility when grown under uniform conditions in the same year.

Roebuck (*13*), working in England, suggested from the available evidence that frit flies were the cause of "blindness" in oats.

Fryer and Collin (*6*) reported that "The percentage of sterile spikelets appears to have no correlation with either of the frit attacks and it is difficult to believe that this pest was in any way concerned in the production of blindness".

Cunliffe (*1*) and Cunliffe and Fryer (*2*), studying the infestation of frit fly in relation to sterility or "blindness" in oats, stated: "If this insect were responsible then percentage sterility should correlate with percentage infestation." No correlation however was found and these authors therefore conclude that frit flies played little or no part in causing "blindness" in oats.

Elliott (4) in a further paper reported that "Varietal differences in the amount of blast appear to be fairly constant from season to season." This author further observed that blast percentage was associated with precipitation during the month of heading and that varieties of hybrid origin were more susceptible to conditions causing blast.

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Huskins (*8*) reported the existence of "specific genetic resistance" to blast and from his data concludes that there is no physiologic relation between blast percentage and panicle size. He pointed out further that it should be possible to breed resistance to blast.

In a study of the inheritance of resistance to blast in oats Mackie (*9*) has shown that varietal resistance is fairly stable. In this work the F_2 progeny gave close agreement to a 1 : 2 : 1 ratio for highly susceptible, moderately susceptible and practical immunity. These results indicate that it is possible to breed for blast resistant varieties.

Considerable work on oat blast has been reported by Rademacher, who concluded in his most recent paper (*12*) that "This abnormality is attributed to defective nutrition at an early stage and may be increased by heavy rainfall, cool or cold weather; and in the case of oats which is a long day type, light deficiency may be a causal factor, but varietal differences probably exist also." In an earlier paper (*11*) this author discussed the effect of origin and environment of the parent seed on blast in the daughter plants. He pointed out that since water supply during the growth of the parent seed is reflected in the development of the progeny, then it might be expected that the environment of the parent seed might also influence the occurrence of blast in its progeny. In this connection, the author concluded that when the parent plants develop under dry conditions there is likely to be found greater resistance to drought in the progeny.

Results of investigational work on oat blast in recent years have therefore shown that sterility of this type is probably physiological. A general summary of recent literature on oat blast and a discussion on the probable causes of the injury is found in Sveriges Utsädesforenings Tidskrift (1932), Vol. 4, page 271. The author of this paper stated that "The damage arising through the presence of an appreciable percentage of empty glumes is not, as has been intimated, one of our most serious difficulties. It is, however, a symptom that the supply of plant food or the moisture conditions of the soil are not right." It was further suggested that choice of variety may also be a factor in the development of blasted spikelets.

OUTLINE OF INVESTIGATIONS

In 1932 a study of oat blast was begun in the Cereal Division, Central Experimental Farm, Ottawa, and in that year some preliminary work to show the effect of different water treatments on the occurrence of blast was carried out under field conditions.

In 1933 a project was outlined to determine the effect of different water and light treatments on the prevalence of oat blast. In the case of the water treatments, an attempt was made primarily to determine to what extent blast was influenced by the application of different amounts of moisture to the young oat plants and secondly to find the critical stage in the early growth of the crop at which different amounts of water would have the greatest influence on the production of blasted spikelets. This work was carried on under greenhouse conditions. On account of the loss of some plants in the water treatment series this part of the experiment was repeated during the winter of 1934-35. In conjunction with the water treatment series, an effort was made to ascertain the effect of different

combinations of light and water treatments on blast development. This work was also carried on in a greenhouse, where the environment, in so far as the factors of light[2] and moisture are concerned, is largely under control.

Data were obtained from the field in 1934 with regard to the influence of date of seeding on the development of oat blast.

Water Treatments

While no statistical analysis was made of the preliminary field work on the effect of different water treatments on blast, it was quite evident that some influence existed. These observations prompted further work. Later investigations were conducted both in the field and in the greenhouse.

In the field test the plants were grown in 10″ pots, which were set in the soil, level with the surface. The pots were divided into three lots, each lot containing 50 plants and subjected to a different water treatment, e.g. reduced water, normal water and excess water. In the case of the reduced water treatment, the plants were given drought conditions by protecting them from natural rainfall. In the normal treatment, the pots were left open to natural precipitation, while the excess treatment consisted of the application of 500 cc. of water to each pot every other day. The treatments started 24 days after seeding, the plants at this time having produced 4 leaves, all plants being given uniform water conditions up to the fourth leaf stage. It was found necessary to apply water twice to the reduced water lot during the course of the test period in order to prevent the plants from drying up completely. The treatments lasted until the appearance of the panicle on the main tiller, after which all three lots were given normal moisture conditions.

The above test was also carried on under greenhouse conditions during the winter of 1933-34. It was possible to control the treatments under glass much more accurately than was the case in the field, although only half the number of plants was used in each lot. The plants in this test were grown in 6″ pots with 5 plants per pot. The amount of soil was uniform for all pots and the soil moisture was brought up to 25% at the start of the test, and in the case of the normal water treatment it was maintained approximately at that level throughout the test by bringing the pots to a constant weight at each watering. With the reduced water treatment, the pots were brought up to 25% moisture at each watering but they were only watered half as often. The excess water treatment consisted of maintaining the soil in a water soaked condition throughout the test. The pots were placed in saucers which were filled with water once a day. All treatments were applied from the fourth leaf stage until the first appearance of the panicle on the main tiller. Counts were made only on main tillers. The variety Banner Ott. 49 was used throughout these tests.

In Table 1 is shown the comparative counts of total and blasted spikelets for the three water treatments under field and greenhouse conditions. The field counts are based on 50 plants per treatment, while the greenhouse data are based only on 25.

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[2] Since the intensity of light during the winter months is much lower than that normally occurring in summer, normal light under greenhouse conditions is not directly comparable to normal light in the field.

TABLE 1.—INFLUENCE OF DIFFERENT WATER TREATMENTS ON THE PRODUCTION OF BLASTED SPIKELETS

	Total number of spikelets	Number of blasted spikelets	% Blast
Field (50 plants)			
Reduced water	1177	430	36 5
Nomal water	1631	381	23 4
Excess water	1720	333	19 4
Greenhouse (25 plants)			
Reduced water	687	445	64 9
Normal water	749	468	62 6
Excess water	1009	492	49.2

It will be observed from these data that the yield of spikelets per plant is fairly uniform in both field and greenhouse but the percentage blast is much higher under greenhouse conditions. It is further evident that with the application of excess water, the spikelet yield increases and the percentage blast decreases. This is true under both conditions of growth.

TABLE 2.—STATISTICAL ANALYSIS OF DATA FROM TABLE 1

	S.S.	D.F.	M.S.	F.	5% Point	Sig. diff.
Field 1934						
Total spikelet No.						
Between treatments	3,392 57	2	1,696 28			
Within treatments	16,030 20	147	109 05	15 6	3.06	4.18
Blasted spikelets						
Between treatments	94 09	2	47 05			
Within treatments	1,817 00	147	12 36	3 8	3 06	1.41
Percentage blast						
Between treatments	6,590 07	2	3,295 03			
Within treatments	15,700 20	147	106 80	30 8	3 06	4.13
Greenhouse 1933 34						
Total spikelets						
Between treatments	2,335 04	2	1,167 52			
Within treatments	1,230 96	72	17 10	68 3	3 13	2 34
Blasted spikelets						
Between treatments	44 12	2	22 06			
Within treatments	516.55	72	7.17	3 1	3 13	1 5
Percentage blast						
Between treatments	3,594 04	2	1,797 02			
Within treatments	3,196 20	72	44 39	40 5	3 13	3 77

The analysis[3] of these data as summarized in Table 2 shows that in the case of spikelet number under field conditions there is considerable variance due to the water treatments, which, when compared with within treatments (experimental error) gives an F value of 15 6. Referring to Snedecor's (*14*) table XXV "Value of F & ι ', we find the 5% point, (for $n^1 = 2$ and $n^2 = 150$) to be 3.06, while the 1% point is 4.75, thus the obtained F value is highly significant. Since a difference of 4.18 between any two treatment means is necessary for significance, the reduced water gives a significantly lower number of spikelets than either of the other two treatments. The number of blasted spikelets also shows a significant

[3] The statistical methods employed in this paper are based on those of Fisher (*5*) and Snedecor (*14*).

difference between treatments (F = 3.8) but not so pronounced as in the case of total spikelet number. Here there is little variance within the various treatments, thus the smaller difference required for significance (1.4) between the treatment means. The treatments in the percentage blast analysis show considerable significance (F = 30.8) which is greater than the 1% point. The excess water had a pronounced influence in decreasing the percentage blast, while reduced water had the opposite effect.

Under greenhouse conditions, although there are only half the number of plants in each, the treatments bear the same relationship as found from field data. For total spikelet number F = 68.3 showing significantly that excess water increases spikelet number. The F value for blasted spikelets (3.08) is below the 5% point, thus there is no significance for treatments generally. On the other hand the treatments are responsible for most of the variance in percentage blast, where F = 40.5. The excess water treatment gave results statistically lower than those for either of the other two treatments when considering blast percentages.

Light Treatments

In an attempt to obtain some information concerning the influence of light on oat blast, another series of pots was grown in the greenhouse (1933–34) and subjected to different combinations of light and water treatments. Pots receiving normal, excess and reduced water were grown under normal, excess and reduced light conditions.

The water treatments for this series were similar to those outlined above. In supplying excess light the pots were placed in a properly aerated enclosure and illuminated by a 100 watt Madza light. Apart from the artificial light supplied to the greenhouse generally, this series of pots received light for an additional two hours each night during the course of the experiment. The reduced light series of pots was protected from artificial greenhouse light by a box similar to the one noted above. In both cases the boxes were removed during the day. The pots receiving normal light were left exposed to the light conditions of the greenhouse, which included artificial light from 6 p.m. until 12 p.m. except in the early stages of growth when the duration of artificial light was 2 hours shorter.

Twenty-five plants were grown in each treatment, the main tiller only being used for blast determinations.

In Table 3 are shown the counts of total and the proportion of blasted spikelets for the three light treatments when subjected to reduced, normal and excess water conditions.

TABLE 3.—LIGHT AS A FACTOR IN THE PRODUCTION OF BLASTED SPIKELETS

	Reduced water		Normal water		Excess water	
	Total spikelets	% Blast	Total spikelets	% Blast	Total spikelets	% Blast
Reduced light	1344	66.8	1755	66.1	1948	55.4
Normal light	687	64 9	749	62 6	1009	49 2
Excess light	503	71 2	645	70.6	813	67.3

From these data it is evident that light has had an appreciable influence in the production of oat blast and that normal light, as supplied under the conditions of the experiment, gave a lower percentage blast than either reduced or excess. With the excess water treatment normal light gave a significantly lower percentage blast than either reduced or excess light. Although in both reduced and normal water treatments, normal light gave a lower percentage blast than the other two conditions of light, excess light alone causes this difference to be significant. Excess light was instrumental in producing the highest percentage blast under any condition of moisture, being significantly higher than the percentages from normal light conditions. Treatments of excess water gave significantly lower percentages of blast under the three conditions of light.

Statistical analysis shows that under any water treatment, reduced light increases the total spikelet number above normal light, the F value being highly significant for all three water treatments. On the other hand, excess light has reduced the yield of spikelets under all water treatments, although only significantly so in the case of the reduced water, where the F value is slightly greater than the 5% point. Light has shown the greatest influence in reducing blast when applied normally with excess moisture. Here the mean 49 2% is significantly lower than any of the other eight percentages.

Critical Period for Blast Development

During the winter of 1934-35 further work was undertaken in the greenhouse to determine the critical period during the development of oat plants when moisture has the greatest influence on blast.

This project consisted of four series of pots each series containing 7 lots of 5 pots each. Six lots of the four series, referred to below as A, B, C and D, received the following water treatments. Series A, normal watering throughout the growing period except that each lot of 5 pots recevied a 14-day period of drought at different stages of growth. Series B received a similar treatment except that the 14-day periods were periods of excess watering. Series C received reduced water throughout the growing period except that each lot of 5 pots was subjected to a 14-day period of excess water at a different stage of growth. Series D received excess water throughout the growing season except for 14-day periods, when drought conditions were administered. Lot 7 of each series was treated as a check and received normal watering throughout.

All pots were normal and uniform as regards soil and soil moisture at the start of the experiment. Reduced water treatments consisted of bringing the soil to 15% moisture at each watering. In pots receiving normal watering the soil moisture was raised to 25%. Pots receiving the excess water treatment were set in saucers which were filled with water once a day.

The first 14-day treatment period started when the plants had reached the fourth leaf stage. These treatments were continued for six periods, the plants having reached the shot blade stage when the last treatment was applied. Series D, which had been given excess water throughout the 84-day treatment period, was somewhat less mature than the other series at the end of the test.

In Table 4 are shown the total number of spikelets and the percentage blast for the seven treatments in each of the four series, each treatment of a series representing a different stage of growth.

TABLE 4.—THE CRITICAL PERIOD OF GROWTH DURING THE DEVELOPMENT OF OATS WHEN MOISTURE HAS THE GREATEST INFLUENCE ON BLAST

Stage of growth after 4th leaf stage (14-day periods or treatments)	Series A Normal moisture with periods of drought		Series B Normal moisture with periods of excess water		Series C Reduced moisture with periods of excess water		Series D Excess moisture with periods of drought	
	Total No. spikelets	% Blast	Total No. spikelets	% Blast	Total No. spikelets	% Blast	Total No spikelets	% Blast
1	724	40 2	769	43 8	588	44 6	1348	68 7
2	601	40 1	962	44 5	930	44 3	1203	62 5
3	651	32 9	1037	44 3	802	52 1	935	51 3
4	748	38 3	662	42 2	474	46 6	1334	57.5
5	732	52 0	743	38 9	492	51 1	1323	52 3
6	765	41 1	793	39 2	471	47 0	1287	48 7
Check (7)	711	36.8	670	32 1	766	39 0	755	29 9

In Series A, which had normal water throughout the test except for the 14-day periods as described above, the application of drought conditions in the fifth treatment or at the fifth 14-day period from the fourth leaf stage increased the amount of blast by 15% over the check or normal water treatment. This figure (52.0%) is statistically significant not only in relation to the check but also to all other treatments in this series. This stage of growth might readily be referred to as the period when drought will have the greatest effect in increasing blast when normal conditions of watering have prevailed during the previous growth of the plants. It is further apparent from the data of Series A in Table 4 that the third treatment is also critical in so far as a drought period affects blast, but at this stage the blast has been greatly reduced. The percentage (32.9) for the third treatment while not significantly lower than the check (treatment 7), is quite significantly lower than all other treatments in this series. One might conclude therefore that there are two critical periods of growth under the conditions of this series, one at the third stage when a 14-day period of drought lowers the blast percentage and one at the fifth stage when drought has the reverse effect. It might be mentioned here that similar results were obtained from work carried on in 1933-34.

The critical period for the total production of spikelets appears to be during the second and third treatments where in Table 4 it is shown that periods of drought have been highly detrimental.

Series B, which received normal watering throughout the test with the exception of 14-day periods of excess water at different stages of growth beginning with the fourth leaf stage, does not appear to have been influenced at any stage during the early growth period. While treatments at all stages gave significantly higher blast percentages than the normally treated check, yet it is again the treatment at the fifth stage that has had the greatest effect in influencing blast percentage. The critical period therefore in the case of excess water treatments is at the fifth stage, which

was also true in Series A. In this case however the tendency of heavy watering periods has been to reduce blast. The treatment of excess water has had a similar influence in stage six; thus it would seem that the added moisture supply affected blast over a wider maturity range than was the case with the reduced water applications in Series A.

Total spikelet number has been significantly increased as a result of periods of excess water during the early stages. This is evident in the second and third treatments. Total yield of spikelets therefore can be greatly influenced by moisture conditions shortly after the fourth leaf stage of growth.

In Series C, where the plants were given reduced water or semi-drought conditions except for 14-day periods of excess water applications at growth stages as described above, the tendency has again been to increase blast when compared with normal moisture conditions. The percentage blast from all treatments is significantly higher than treatment 7, the normally watered check lot. The smallest amount of blast is found in the first two treatments or during the earlier stages of growth. The young plants at this stage were more favourably affected than when more mature. From a statistical standpoint a difference of 4.68 in blast percentage between any two treatment means is significant. This difference indicates first, that all treatments give significantly higher percentages of blast than the check, and second, that stages one and two are significantly lower in blast percentage than stages three or five but not lower than stages four and six. It is difficult to explain the conflicting blast percentages in stages three to six but it seems significant that the least amount of blast occurred during the early growth as a result of the application of excess water at that stage. While the data do not point to any definite period as being critical under the moisture conditions prevailing, yet the indications are that the early growth period is critical in so far as blast reduction is concerned in a crop suffering from drought.

It is evident from the data of Series C that total spikelet number is influenced quite definitely during the second and third stages when compared with the other 14-day periods of excess moisture. Although only period two is significantly greater than the check, the other four 14-day periods produced a lower total spikelet number. This seems to indicate that, except for the critical stages (periods two and three), periods of excess moisture during normally dry conditions materially lessen the yield of oat spikelets.

In Series D the moisture conditions are the reverse of those in Series C, excess water being applied throughout the test except for 14-day periods of drought beginning with the fourth leaf stage of growth. Data on this series in Table 4 show that drought conditions during the first two stages or treatments have influenced blast adversely and that the blast percentages for these stages and particularly the first stage are quite significantly higher than any other. This early growth period might therefore be called the critical period of blast development under the moisture conditions of the series. The reduction in blast has been most effectively lowered in this series by the application of drought during the sixth stage or just before heading. All water treatments give significantly higher percentages of blast than the normal treatment.

The critical stage for total spikelet development is shown to be the third. At this period there is a significant reduction in spikelet number when compared with the other five water treatments, although all treatments yield higher than the check group. Excess water throughout the season even with the set-back brought about by the 14-day drought periods, has tended to raise the total spikelet number above that of other series except in the case of treatments three and six.

Influence of Dates of Seeding on Blast

It has been commonly observed that blast is more prevalent on late sown crops and likewise on late tillers.

In 1934 a preliminary test was conducted to determine the effect of different seeding dates on blast development. Counts were made on plants seeded at four different dates from April 30 to May 15. An analysis of the data for total spikelet number, failed to show any significant difference between the four dates; however, when the percentage blast was considered, there was significance but only between the two extreme dates. That is to say, later seeding gave a significantly higher percentage blast than the earlier sowing. One might be inclined to conclude further that this test bears out the previously noted fact, that there is no correlation between total spikelet number and percentage blast.

DISCUSSION

A review of the literature indicates that blast or blindness of oats has been known for considerable time, but its suggested causes have been variable. Thrips, halo blight, light, moisture supply and nutrient deficiencies have been suggested as reasons for blast. First, the idea of thrip infestation was discarded as a logical reason for the injury, and later the halo blight suggestion was discarded as an inadequate solution.

More recently evidence has been submitted which associates blast injury with moisture, light and nutrition and further that genetic differences between varieties exist. These differences indicate the possibility of breeding for blast resistance.

The chief objects of the investigations reported in this paper have been to determine the optimum conditions of moisture and light which favour the maximum production of fertile spikelets and to find at what stage of growth the oat plants are most susceptible to adverse conditions of growth, in so far as blast is concerned.

Various water treatments were investigated from which it was shown that under both field and greenhouse conditions excess moisture lowered the percentage blast, although only under conditions in the greenhouse is this difference significant when compared with the normal water treatment. Excess water treatments produced the greatest number of spikelets under both conditions but again this difference is only significantly greater in the case of normal moisture treatment under greenhouse conditions. It would seem that the stage at which the moisture was applied to the oat plant has an influence on both spikelet number and percentage blast. Huskins (*4*) suggested that resistance to blast may be combined with high spikelet number per panicle, and concluded "that specific genetic resistance to blindness exists, and that differences in degree of blindness

are not due to a general physiological correlation with panicle size." Data from the investigations herein reported show a $-.0129$ correlation coefficient for percentage blast and total spikelet number when the significant level is .159.

Elliott (*2*) observed that blast percentage was associated with precipitation during the month of heading. These observations are confirmed in the present paper and from data presented in Table 4 it is clear that there are critical periods at which the moisture supply influences both the percentage blast and total spikelet number. These periods vary according to the conditions of moisture that the plant has passed through during the earlier stages of growth. A sudden period of either excess moisture or drought during a stage when the young oat panicle is beginning to differentiate would greatly influence its subsequent yield, favourably in the case of added precipitation and unfavourably where the drought condition exists. These results seem to indicate that the critical period is about six or eight weeks after seeding, depending upon the prevailing climatic conditions.

Rademacher (*12*) showed that light was also a causal factor in blast production. The investigations herein discussed have confirmed these findings and have shown that reduced light tends to increase spikelet number under any condition of moisture but is effective in reducing blast only when compared with excess light and particularly under excess water treatment. Normal light produces the lowest percentage blast under any water treatment, but here again the difference is only significant under heavy water applications. Excess light gave the lowest spikelet number, this influence being significantly effective only in the case of reduced water application. Blast percentage was increased quite considerably by excess light under any water treatment. From a practical standpoint it would seem that cool cloudy weather six to eight weeks after seeding in the field has a tendency to increase the yield of spikelets, but the moisture supply interacts with the light conditions to produce varying percentages of blast. The combination of normal light conditions with excess moisture supply favours the reduction of blasted spikelets.

Rademacher (*11*) has pointed out that there is a direct relationship between date of seeding and blast percentage. Late seeding was shown to produce the highest percentage of blast. This conclusion has been confirmed from data obtained during the course of this investigation and while the interval between the first and last seeding was only fifteen days, yet there was a significant difference in blast percentage between the extreme seedings. When seeded late, there is ordinarily a forced, rapid growth on account of the higher temperatures. The critical period for blast development will, under these conditions, more likely fall during a drier, hotter period than would be the case with early seeding. Such conditions of environment, as shown in Series A, Table 4, favour blast development at certain stages of growth. It is assumed therefore that in delaying the critical period for blast development by late seeding, more favourable conditions exist for the blasting of those late maturing spikelets that otherwise might have developed normally under the environment of earlier seeding.

SUMMARY

1. Moisture is an important factor in blast development. The application of excess water is most effective in reducing blast under both field and greenhouse conditions.

2. Light, a factor in blast reduction, is most effective when applied normally, and particularly when combined with excess water.

3. The critical period for blast development, as shown by the influence of water and light, appears to be from six to eight weeks after seeding, this period varying with the moisture supply.

4. Late seeding increases blast production. It has also been observed that late tillers are more susceptible to conditions favouring blast.

5. Statistical analysis shows no significant correlation between percentage blast and total spikelet number.

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BIBLIOGRAPHY

1. CUNLIFFE, N. Studies on Oscinella Frit. Linn. Ann. App. Biol. *17* : 3; 549. 1930.
2. ———— – and FRYER, J. C. F. Oscinella Frit. Linn. An Investigation to determine how far varietal differences may influence infestation of the oat plant. Ann. App. Biol. XI, 3 and 4; 465. 1924.
3. ELLIOTT, MISS C. Sterility of oats. U.S.D.A. Bull. 1058. 1922.
4. ————. Oat blast. Phytopath. *15* : 9; 564. 1925.
5. FISHER, R. A. Statistical Methods for Research Workers. (4th ed.) 1932, Oliver and Boyd, Edinburgh.
6. FRYER, J. C. F. and COLLIN, J. E. Certain aspects of the damage to oats by the Frit Fly. Ann. App. Biol. XI : 3 and 4; 448. 1924
7. HEWITT, C. G. Sterility in oats caused by thrips. J. Econ. Entom. 7 : 2; 211. 1914.
8. HUSKINS, C. L. Blindness or blast of oats. Sci. Agr. *12* : 4; 191. 1931.
9. MACKIE, W. W. Inheritance of resistance to blast in oats. Phytopath. *18* : 11; 948. 1928.
10. MANNS, T. F. The blade blight of oats, a bacterial disease. Ohio Agric. Exp. Sta. Bull. 210; 91. 1909.
11. RADEMACHER, B. Die Weissährigkeit des Hafers, ihre verschiedenen Ursachen und Formen. Archiv. Für Pflanzenbau, *8* : 3; 456. 1932.
12. ————. Weitere Untersuchungen über die Ursachen der Flissigkeit beim Hafer und deren Abhangigkeit von der Herkunft des Saatgutes. Arb. a-d Biol. Reichsanstalt Für Land.—und Forstwirtschaft. *20* : 5; 587. 1933.
13. ROEBUCK, A. Frit fly (Oscinis Frit) in relation to blindness in oats. Ann. App. Biol. 7 : 2 and 3; 178. 1920.
14. SNEDECOR, G. W. Analysis of Variance and Covariance. Collegiate Press. Inc. 1934.

Résumé

Une étude des causes de la "Coulure" (Blast) de l'avoine. R. A. Derick et J. L. Forsyth, Ferme expérimentale centrale, Ottawa, Ont.

L'humidité est un facterur important dans le développement de la coulure. L'application d'une quantité excessive d'eau aide beaucoup à réduire la coulure, aussi bien dans les conditions de pleine terre que dans celles de la serre. La lumière, qui est un facteur dans la réduction de la coulure, est surtout utile lorsqu'elle est appliquée normalement, et spécialement lorsqu'elle est combinée avec un excès d'eau. La période critique pour le développement de la coulure, démontrée par l'effet de l'eau et de la lumière, paraît être de six à huit semaines après les semailles; elle varie avec la proportion d'humidité. Les semailles tardives augmentent la coulure. On a remarqué également que les plantes tallant tard sont plus sensibles aux conditions qui favorisent la coulure. L'analyse statistique n'indique aucune corrélation significative entre le pourcentage de coulure et le nombre total d'épillets.

A SIMPLE METHOD OF HEAD THRESHING[1]

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A simple and rapid method for threshing single heads or panicles of cereals and grasses has been developed. This method promises to be very useful wherever it is necessary to keep separate the seed of a single inflorescence or plant.

A diagram of the apparatus is shown in Figure 1. It consists of a piece of used bicycle tubing (A) 16 inches long, which slips over a grooved collar. Used bicycle tubing has been found to be more satisfactory than new tubing since the latter is usually flattened and creased. Between the

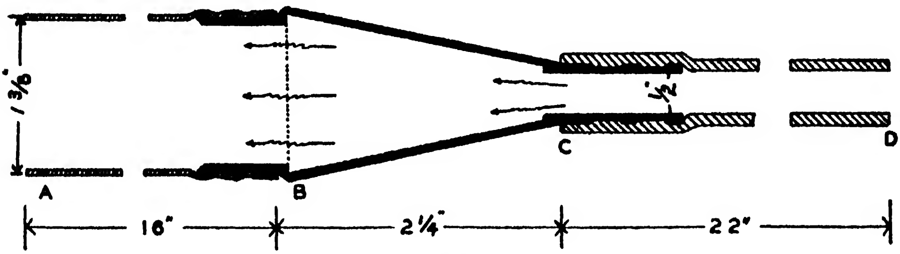

FIGURE 1.

grooved collar and the funnel a 60-mesh brass woven-wire screen is soldered in place (B. Figure 1). This serves to equalize the air flow over the area of the opening. The small end of the funnel is connected by 22 inches of rubber tubing to a cock on a compressed air line.

In one of the tests, a portable air compressor operated by a ¾-horse power motor was used to provide the necessary air flow for satisfactory cleaning. This was obtainable with pressures as low as 15 pounds. Since this machine is capable of giving pressures of 200 pounds, a smaller unit should serve the purpose. The air line serving the laboratories, which carries a pressure of 80 pounds, was used in another test with excellent results. The initial air flow was reduced and set by means of a needle valve. Final control during threshing was obtained with an ordinary lever-armed valve. While the above tests indicate that hand control of widely different pressures is satisfactory, the installation of an automatic pressure reducing valve might be advantageous. If a suitable compressor is not available, it is probable that the air flow provided by a small multi-blade blower fan or a domestic vacuum cleaner fan would be satisfactory.

The heads or panicles are threshed inside the bicycle tubing by rubbing with a rolling motion against a smooth flat surface. The bicycle tubing is then held up at a suitable angle and the air turned on. By shaking the

[1] Contribution from the Division of Biology and Agriculture, National Research Laboratories, Ottawa.
[2] Biologist.

apparatus and varying the angle and air flow any refinement of separation can be readily obtained. The air pressure combined with the shaking keeps the seeds agitated and permits the chaff to be quickly carried out of the end of the tube. The air is then turned off and the clean seeds emptied into an envelope. This method has been found to work equally as well with heavy grains such as wheat, oats, barley, and rye as with the light seeded grasses such as timothy and red top. Difficulty may be experienced in inserting large widely branched panicles in the size of tubing illustrated. For crops possessing this type of inflorescence a larger threshing tube would probably be more suitable.

Where head threshing methods are necessary it is usually very important to reduce threshing damage to the minimum. This appears to be possible with this method as evidenced by the fact that oats can be threshed without breaking off the dorsal arm, and barley with little danger of breaking the hull.

Tests on the rate of threshing with barley have shown that one person can thresh over 200 heads an hour providing the clipped heads are ready and no time is allowed for labelling. This rate is the same as that calculated for the head threshing machine developed by Kemp (*1*).

REFERENCE

1. Kemp, H. J. Sci. Agric. *15* : 488-506. 1935.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

The index number of wholesale prices in Canada declined from 72.3 in May to 71.5 in June. The index of vegetable product prices dropped from 68.0 to 66 1. Animals and their products fell from 69 5 to 68 7. Non-ferrous metals and their products declined from 70 7 to 69 6. Less striking recessions occurred in iron and its products, and fibres, textiles and textile products. Gains were reported in the wood, wood products and paper group as well as in non-metallic minerals.

Retail Prices.—The index of retail prices was unchanged in June. The index of food prices was slightly higher, that of clothing was slightly lower and prices of fuel were noticeably less than in May.

The value of retail sales was well maintained in June, the index being 71 8 compared with 72 4 in May and 72 6 in June of last year. The decline in June was less than in any of the previous four years. The lower level in June of this year could be explained by the fact that there was one less selling day during the month of June 1935 than in June 1934. The May to June change in 1935 represented a decline of 0 8%. In 1934, the change was 3 6% downward while in 1933 it was 2 5% and in 1932, 2 6%.

Physical Volume of Business.—The index of the physical volume of business reached a high point of 103 2 in May. This level was not maintained in June but business was still at a high level the index being 99 2. Industrial production showed a similar decline for the index dropped to 99 7. Mineral production was down nearly five points. Shipments of silver were somewhat higher but those of gold were considerably lower, and coal production was under that of May

The index of manufacturing dropped from 105 1 to 98 4 There was a slight increase in manufacture of sugar, imports of textiles, particularly those of cotton and wool, were higher than during the previous month. Exports of shingles were considerably above those of May. Pig iron production was higher. Steel production advanced about three points. Construction also showed improvement and the index rose from 38 1 to 43 7. Trade employment was slightly higher than in May. Car loadings were lower and both exports and imports were down.

Generally speaking, there was a general easing down in production which was responsible for the decline in the index.

Among the agricultural factors, grain marketings were substantially above those in May, the index rising from 85 4 to 112 3. All classes of grain moved in larger volume. The index of live stock marketings moved downward from 90 6 to 78 2. There was, however, a large gain in marketings of calves.

Cold Storage Holdings.—The index of cold storage holdings as of June 1 was slightly higher than as of May 1. This was due to the increased stocks of beef, mutton, pork and lard. There were substantial reductions in eggs, butter, cheese, poultry and meat.

Prices of Agricultural Products. The index number of wholesale prices of Canadian farm products showed the first sharp decline in some months, falling from 64.1 to 61.4. The index prices of field products dropped from 58 0 to 55.1. The average price of No. 1 Manitoba Northern wheat was 85.7 cents per bushel in May compared with 81.7 in June. No. 2 C. W. oats declined from 40 8 to 39.8. No. 2 C. W. rye fell from 46.0 to 41 2. No. 3 C. W. barley averaged 39.2 cents per bushel in June which represented a decline of 3.1 cents per bushel. The index of prices of animal products declined from 74.2 to 72 0. Prices generally were lower although

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65 5	69 2	64.9	79.0	66 0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88 4	92.3	72.5				
1917	114.3	130.0	134 3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110 0	102.8	100.3	108.5	109.2	66.5	60 4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100 0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100 0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102 6	100 4	98 1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102 1	99 9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93 8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70 0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90 4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81 4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1934	71.6	59 0	53.9	67.6	78.9	94.2	93.6	88.5	114.2
1934									
Jan.	70.6	55 3	47.9	67 8	78.2	86 8	84.5	48.2	108.1
Feb.	72.1	58 0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr	71.1	55 4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78 5	99.6	99.4	130 6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72 0	60.0	57.8	63 7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172 8	114.7
Sept.	72.0	61.3	58.9	65.3	79 0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.8
Nov.	71.2	61.2	55.7	70.4	79.4	96.5	97.0	51.2	130.4
Dec.	71.2	61.6	56.0	70.9	79.0	92.4	91.0	36.0	135.7
1935									
Jan.	71.5	61 4	55.7	71.0	78.9	97.5	97.8	30.6	143.7
Feb.	71 9	62 0	55.7	72 6	79 1	100.6	101 1	62.2	141.2
Mar.	72.0	62.7	56.4	73.3	79.0	94.2	93.3	65.4	143.2
Apr.	72 5	64 7	59 8	72.9	78 8	98 3	97 7	91.8	135.8
May	72 3	64 1	58.0	74 4	78 7	103.2	104.4	86.3	123.2
June	71.5	61.4	55 1	72 0	78.7	99 2	99.7	106.1	125.0

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1933, p. 15.

2. Wholesale prices of Canadian products of arm origin only. See Prices and Price Indexes 1913-1933, p. 33, and Monthly Mimeographs 1933 and 1934.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries. See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.

Prices and Price Indexes 1913-1931, p. 108, and Monthly Mimeographs 1933-1934.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical Volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

hogs were higher and good handyweight lambs averaged higher prices at Toronto than was the case during May. Prices of butter were lower while those of eggs were higher in principal markets.

Prices in Great Britain.—The monthly index of prices of agricultural produce (corresponding months 1911 — 13 = 100) was 111 in May compared with 119 in April. Seasonal trends are given as a partial explanation of the decline. Prices of fat cattle and potatoes were considerably better, but the price of milk was lower because of the adjustment in the regional contract price to the summer level. Prices of butter were slightly lower but cheese was higher. Eggs were also higher than in April but ducks and fowls were cheaper. Bacon pigs were lower.

United States Prices.—Index numbers of farm prices in United States (August 1909, July 1914 = 100) were 4 points lower than in May, the index declining from 108 to 104. Prices of fruits and meat animals advanced but indexes of other commodities declined. In the case of grains, the index fell from 112 to 102. Cotton and cottonseed declined from 105 to 103. Truck crops dropped from 127 to 96. Dairy products lost 7 points, the index for June being 100. The index of prices of chickens and eggs declined from 110 to 108. Prices paid by farmers for commodities bought were unchanged but the ratio of prices received to prices paid was 82 compared with 85 in May.

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE, OTTAWA, PRINCIPALEMENT D'APRÈS LES DONNÉES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

Le chiffre-indice des prix du gros au Canada qui était à 72.3 en mai est tombé à 71.5 en juin. L'indice des prix des produits végétaux a rétrogradé de 68 0 à 66.1; celui des animaux et leurs produits de 69.5 à 68.7, et celui des métaux non ferreux et leurs produits de 70.7 à 69.6. Il y a eu d'autres régressions moins fortes dans le fer et ses produits et dans les fibres, textiles et produits textiles. D'autre part, on signale des gains dans le bois, le groupe des produits du bois et du papier ainsi que dans les minéraux non métalliques.

Prix du détail.—L'indice des prix du détail n'a pas changé en juin. L'indice des prix des aliments était un peu plus élevé, celui des vêtements un peu plus bas et les prix du combustible sensiblement moins élevés qu'en mai.

La valeur des ventes au détail a été bien maintenue en juin; l'indice était de 71 8 contre 72.4 en mai et 72 6 en juin de l'année dernière. La diminution de juin est la plus faible que l'on ait enregistrée depuis quatre ans. Le niveau plus bas constaté en juin peut s'expliquer par le fait qu'il y a eu un jour de vente de moins pendant le mois de juin 1935 que pendant le mois de juin 1934. Les changements de mai à juin en 1935 représentent une diminution de 0 8 pour cent. En 1934, la diminution avait été de 3.6 pour cent, en 1933 de 2.5 pour cent et en 1932 de 2 6 pour cent.

Volume physique des affaires.—L'indice du volume physique des affaires a atteint le point élevé de 103 2 en mai. Ce niveau n'a pas été maintenu en juin mais l'indice est resté assez élevé, 99.2. La production industrielle accusait une diminution semblable car l'indice est tombé à 99.7. La production minérale a baissé de près de cinq points. Les expéditions d'argent étaient un peu plus fortes mais celles d'or beaucoup plus faibles et la production de charbon était inférieure à celle de mai.

L'indice des industries manufacturières est tombé de 105.1 à 98 4. Il y a eu une légère augmentation dans la fabrication du sucre; les importations de matières textiles, spécialement de coton et de laine, ont été plus considérables que pendant le mois précédent. Les exportations de bardeaux ont été sensiblement plus élevées qu'en mai. La production de fer en gueuse a été plus forte. La production de l'acier a avancé d'environ trois points. L'indice du bâtiment s'est aussi un peu amélioré, passant de 38.1 à 43.7. L'emploi dans le commerce a été un peu plus élevé qu'en mai, cependant les chargements de wagons ont diminué et il y a eu diminution dans les exportations aussi bien que dans les importations.

Parlant d'une façon générale on peut dire qu'il y a eu un léger fléchissement de la production, qui a provoqué la baisse de l'indice.

Parmi les facteurs agricoles, les ventes de grain ont été bien supérieures à celles de mai, l'indice passant de 85.4 à 112.3. Les expéditions de toutes les catégories de grains ont été plus fortes. L'indice des ventes du bétail est descendu de 90.6 à 78.2; il y a eu cependant une forte augmentation dans les ventes de veaux.

Stocks conservés au froid.—Au 1er juin l'indice des stocks conservés au froid était un peu plus élevé qu'au 1er mai à cause de l'augmentation des stocks de bœuf, de mouton, de lard et de saindoux. Il y a eu des diminutions sensibles dans les stocks d'œufs, de beurre, de fromage, de volailles et de viande.

Prix des produits agricoles.—Le chiffre-indice des prix de gros des produits agricoles canadiens a accusé la première baisse sensible qui ait été enregistrée depuis quelques mois; il est tombé de 64.1 à 61.4. L'indice des prix des produits des champs est tombé de 58.0 à 55.1. En juin le prix moyen du blé du nord Manitoba N° 1

était de 81.7c. le boisseau contre 85.7c. en mai. L'avoine N° 2 C.O. est tombée de 40.8 à 39.8 le seigle N° 2 C.O. de 46.0 à 41.2. L'orge N° 3 C.O. était en moyenne à 39.2c. le boisseau en juin, représentant une diminution de 3.1c. par boisseau. Le chiffre-indice des prix des produits des animaux est tombé de 74.2 à 72.0. Les prix en général étaient plus bas, mais les porcs étaient plus élevés et les agneaux d'un bon poids ont obtenu en moyenne de meilleurs prix à Toronto qu'en mai. Les prix du beurre ont diminué tandis que ceux des œufs se sont relevés sur les principaux marchés.

Prix en Grande-Bretagne.—L'indice mensuel des prix des produits agricoles pour les mois correspondants (1911 — 13 = 100) était à 111 en mai contre 119 en avril. Cette diminution s'explique en partie par les tendances saisonnières. Les prix des bœufs gras et des pommes de terre étaient bien meilleurs mais le prix du lait a diminué à cause de l'ajustage du prix régional de contrat au niveau de l'été. Les prix du beurre étaient un peu plus bas mais ceux du fromage plus élevés. Les œufs se vendaient également plus cher qu'en avril mais les canards et les volailles étaient meilleur marché. Les porcs à bacon étaient plus faibles.

Prix aux Etats-Unis.—Les chiffres-indices des prix des produits de ferme aux Etats-Unis (août 1909, juillet 1914 = 100) étaient de 4 points plus bas qu'en mai; l'indice tombant de 108 à 104. Les prix des fruits et des viandes ont augmenté tandis que les indices des autres produits diminuaient. L'indice des grains est tombé de 112 à 102, celui du coton et de la graine de coton de 105 à 103. Les récoltes maraîchères ont passé de 127 à 96. Les produits laitiers ont perdu 7 points; l'indice pour juin est de 100. L'indice des prix des poulets et des œufs a baissé de 110 à 108. Les prix payés par les cultivateurs pour les marchandises qu'ils achetaient sont restés les mêmes, mais la relation entre les prix reçus et les prix payés n'était que de 82 contre 85 en mai.

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